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E-mail: civil@davidpublishing.com; civil@davidpublishing.org; shelly@davidpublishing.com

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Environmental Impact Optimization of Reinforced Concrete Slab Frame Bridges

Majid Solat Yavari[1, 2], Guangli Du[3], Costin Pacoste[1, 2] and Raid Karoumi[1]

1. KTH Royal Institute of Technology, Division of Structural Engineering and Bridges, 100 44 Stockholm, Sweden;

2. ELU Konsult AB, 102 51 Stockholm, Sweden;

3. The Faculty of Engineering and Science, Danish Building Research Institute, Aalborg University Copenhagen, 2450, Denmark

Abstract: The main objective of this research is to integrate environmental impact optimization in the structural design of reinforced concrete slab frame bridges in order to determine the most environment-friendly design. The case study bridge used in this work was also investigated in a previous paper focusing on the optimization of the investment cost, while the present study focuses on environmental impact optimization and comparing the results of both these studies. Optimization technique based on the pattern search method was implemented. Moreover, a comprehensive LCA (life cycle assessment) methodology of ReCiPe and two monetary weighting systems were used to convert environmental impacts into monetary costs. The analysis showed that both monetary weighting systems led to the same results. Furthermore, optimization based on environmental impact generated models with thinner construction elements yet of a higher concrete class, while cost optimization by considering extra constructability factors provided thicker sections and easier to construct. This dissimilarity in the results highlights the importance of combining environmental impact (and its associated environmental cost) and investment cost to find more material-efficient, economical, sustainable and time-effective bridge solutions.

Key words: LCA, slab frame bridge, environmental impact, structural optimization, pattern search.

1. Introduction

Today's construction sector is an essential contributor to economic development, but is also responsible for the consumption of a large amount of energy and raw materials. In 2015, the construction sector in Sweden represented 10% of GDP (gross domestic product) and involved 311,000 people at an investment level of 388 billion Swedish Krona [1]. The construction of bridges, a fundamental type of infrastructure, plays an important role in this highly active industry. Accordingly, the reduction of the environmental impacts of bridges is important and should be taken into consideration in order to achieve a sustainable and environmentally friendly design [2].

In recent decades, researchers have applied several optimization algorithms in order to determine the optimal design of different structures. Most of these methods concern the cost of the structure, in which reducing cost is the main objective, while environmental performance and other associated costs are rarely integrated into the optimization process. For instance, in a previous study performed by Yavari, Pacoste and Karoumi [3], cost-optimized designs of slab frame bridges were compared, showing the potential to reduce the cost of investment. This methodology was successfully applied for the automated and cost-optimal design of a new slab frame bridge, one of which has since been constructed [4]. However, the criteria of sustainable design and environmental performance should also be taken into account during decision-making in addition to technical feasibility, durability and cost. The use of multidimensional criteria may lead to controversy: the most environmentally friendly solution may not be the cheapest or the most efficient one with regard to the

Corresponding author: Majid Solat Yavari, technologie licentiat; research fields: structural optimization, structural design, and LCA. E-mail: majidsy@kth.se.

construction process. These conflicts should be considered early on in the design phase [2].

LCA (life cycle assessment) is a comprehensive, standardized and internationally recognized approach for quantifying all emissions, resource consumption and related environmental and health impacts linked to a service or product during its entire life cycle. It has the potential to provide a reliable environmental profile of structures; thus, it can be used in structural optimization design to assist decision-makers in selecting the most environmentally friendly solution. However, most LCA analyses are performed on existing designs at a stage in which it is too late to make any improvements [5, 6]. Therefore, this paper attempts to integrate LCA with a design optimization approach in the early planning phase in order to effectively incorporate multiple criteria, including environmental impacts and associated cost. Accordingly, in this paper, structural optimization is performed for concrete slab frame bridges by considering the environmental impacts of different designs and their associated costs.

LCA has seldom been used in the study of bridges [7]. Most previous studies have considered either a single indicator or only a few structural components. For example, Widman [8], Itoh and Kitagawa [9], Itoh et al. [10], Martin [11], Collings [12], Bouhaya et al. [13] and Habert et al. [14, 15] focused on energy consumption and CO_2 emissions; meanwhile, Martin [11], Keoleian et al. [16] and Bouhaya et al. [13] confined the scope of their analysis to the bridge deck. According to the extensive literature review of Pieragostini et al. [17] on optimization performed with LCA methodology, most previous studies considered a single environmental impact in the objective function. Some examples of studies that mainly consider embedded energy or CO_2 emissions are as follows: Camp and Assadollahi [18] in the optimization of reinforced concrete footings; Yepes et al. [19] in the optimization of reinforced concrete retaining walls; Cho et. al [20] in the optimization of high rise steel structures; Yeo and Gabbai [21] and Yeo and Potr [22] in the optimization of reinforced concrete frame structures; Ji, Hong and Park [23], in the decision-making process of nine structural building designs; and Paya-Zaforteza et al. [24] in the minimization of CO_2 emissions of reinforced concrete building frames.

In addition to global warming, environmental sustainability also encompasses other indicators related to human health and the depletion of natural resources. Therefore, the environmental impact analyses focusing exclusively on global warming potential will not provide a full profile of potential environmental impacts [25]. Consequently, this research uses the ReCiPe method (described in the following) to cover not only global warming but also other important indicators regarding human health and the deterioration of natural resources. The current study is the first, to the best of the authors' knowledge, to evaluate the structural optimization of slab frame bridges considering all important environmental impact indicators. Regarding optimization of similar structures to slab frame bridges, Perea et al. [26] have presented cost optimization of 2D reinforced concrete box frames used in road constructions. In another work, Lombardero, Vidosa and Yepes [27] have studied optimization of reinforced concrete vaults used in road construction and hydraulic artificial tunnels.

Furthermore, involving the environmental cost into the total project cost has attracted increasing research interests. For instance, Park et al. [28] presented an optimization method to minimize the associated cost of CO_2 emissions given the use of composite steel reinforced columns in high-rise buildings. In their study, CO_2 emissions were transformed to cost using the unit carbon price; this cost was then added to the cost of materials and labor, in order to achieve a more sustainable design. In another study, Medeiros and Kripka [29] compared the environmental optimization of rectangular reinforced concrete columns based on several parameters (global warming potential, CO_2

emission and energy consumption) with the cost optimization based on different optimization methods. Additionally, by using simulated annealing method Paya et al. [30] have performed multi-objective optimization of reinforced concrete building frames considering cost, constructability, and environmental impacts.

In the previous study of Yavari, Pacoste and Karoumi [4], a complete automated design and structural optimization considering investment cost was performed on realistic 3D model of concrete slab frame bridges. The obtained results showed the efficiency of the applied algorithms in the cost optimization of slab frame bridges. This methodology was applied during the design process of a concrete slab frame bridge to achieve a time-effective and cost-optimal design. In the current study, the optimization of environmental impacts is considered for the same bridge in order to compare the most economical and the most environment-friendly designs. For this purpose, the same assumptions (e.g., input variables, constraints, stopping criteria, etc.) were adopted and the only difference was in the objective function. The results of this comparison will contribute to establishing a combined methodology that considers both investment cost and environmental impacts in the design process, allowing for a more sustainable design of slab frame bridges.

2. Method

2.1 Optimization Process

In the abovementioned study of Yavari, Pacoste and Karoumi [4], a code with several modules was developed to produce parametric models of slab frame bridges. In the current study, the same code was used to study the environmental impacts of slab frame bridges. The automated design and iterative optimization process are presented in Fig. 1. The modeling and application of all relevant loads were performed in Module 1. Module 2 included structural analysis in 3D in the commercial finite element program, Abaqus Ver. 6.12, as well as the extraction of section forces and load combinations. In a separate developed program, the necessary reinforcement to satisfy requirements of ULS (ultimate limit state), SLS (serviceability limit

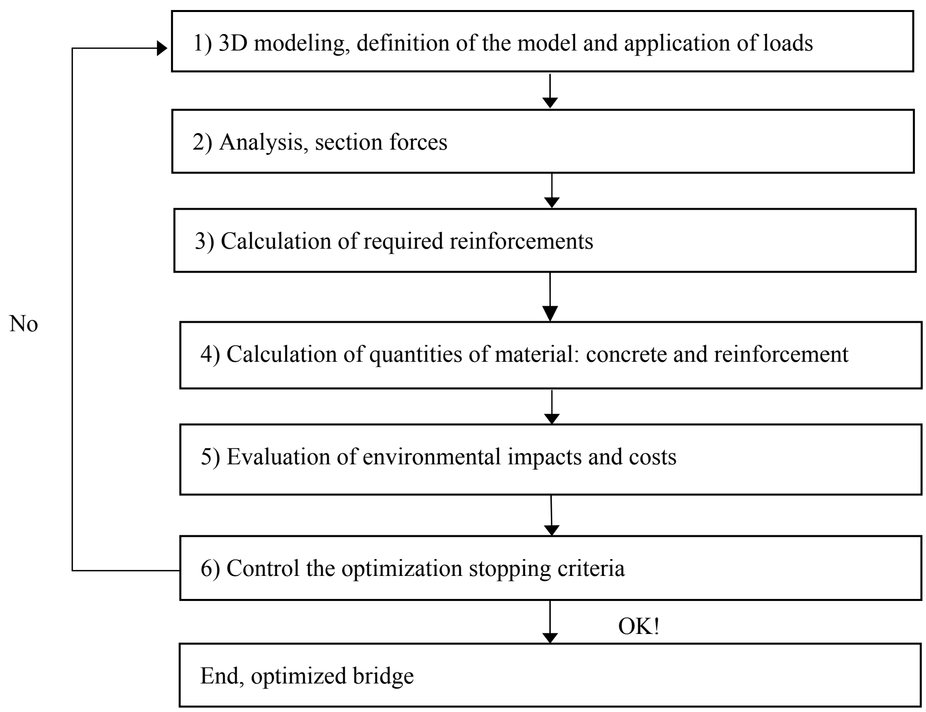

Fig. 1 The automated design and optimization process of a slab frame bridge [4].

state), fatigue checks and other design and constructability requirements for the whole bridge (constraints) were calculated as part of Module 3. In the following modules, the quantities of concrete and reinforcements, as well as the total environmental impacts of the bridge and its associated cost (objective function) were performed based on the ReCiPe method and the two monetary weighting systems. This process was performed by an optimization algorithm until the stopping criteria was fulfilled.

The results of the previous study showed that the PS (pattern search) method was more effective than the GA (genetic algorithm) in the cost optimization of the case study bridge. Therefore, the same algorithm and stopping criteria were also implemented in this study in order to utilize the same assumptions and render the results comparable. The PS method is a robust and efficient method that can perform well in optimization models that contain discontinuous, stochastic or random data types. This method is useful for problems not easily solved by mathematical or gradient-based algorithms. The MATLAB optimization toolbox was used for the optimization [31]. At each iteration, the pattern search method generates a set of points (variables), creating a "mesh", by adding the current point to some vectors, which is called the pattern. The pattern search method examines this set of points, searching for one with a lower objective function value ("polling"). If the algorithm finds a point in the new mesh with a lower objective function value, this point becomes the current point for the next step; otherwise, the algorithm generates and examines a new set of points around the current point. This process continues until the stopping criterion is met. Stopping criteria in optimization define the point at which the calculation can be stopped, terminating the process of finding the optimum value. It is important to select proper stopping criteria for each optimization problem. However, it should be considered that in practical engineering, it is often more important to have solutions that improve the initial design as desired rather than finding the lowest objective function value. In other words, in practical problems, we often desire to find a solution that is "good-enough" in a specific time domain rather than finding the global optimum [32]. In the following case study, the function tolerance of less than 0.05 (alteration in the resulting value of the objective function in two successive iterations) or a total calculation time of 10 hours (as a practical time limit) was considered as stopping criteria by the PS method (according to whichever criterion was met earlier). More information about the applied optimization algorithm has been presented in the previously published study of Yavari, Pacoste and Karoumi [4].

2.2 ReCiPe Method

Among the various existing LCA methodologies for interpreting environmental impacts [33], this paper considers the most comprehensive LCA methodology of ReCiPe midpoint (H) [34], which is the combined method of Eco-indicator 99 and CML 2002 including state-of-the-art impact categories [35]. The LCA modeling covers more than 1,000 substances within each material, from which the characterized impacts of CED (cumulative energy demand) and 11 types of mid-point impact categories are selected, namely GWP (global warming), ODP (ozone depletion), HTP (human toxicity), POFP (photochemical oxidant formation), PMFP (particulate matter formation), TAP (terrestrial acidification), FEP (freshwater eutrophication), MEP (marine eutrophication), TETP (terrestrial ecotoxicity), FETP (freshwater ecotoxicity) and METP (marine ecotoxicity). The comprehensive involvement of impact indicators remedies the absence of full spectrum of environmental indicators in the current state-of-the-art [7]. The study attempts to cover the environmental indicators as comprehensive as possible, however, this is not applicable due to limited availability of monetary values in practice. Therefore, in the objective function of optimization, only indicators available in both weighting methods are further considered and presented in Tables 1 and 2.

Furthermore, a cradle-to-grave "market" analysis was considered in the LCA (i.e., including the extraction, procurement, transportation of raw materials to the building site and waste of the product in trade and transport). Table 1 presents the environmental impacts of reinforcement and different concrete types evaluated in this study based on the ReCiPe midpoint method (H) V1.12. Long-term emissions are omitted and emissions due to infrastructure process are included. These impacts were calculated with data from the Ecoinvent version 3 database in the commercial LCA software SimaPro 8.2.0.

2.3 Monetary Evaluation of Environmental Impacts

The LCA modeling covered parameters of human health, ecosystem quality and resources, which are not straightforward to assess at the decision-making level without in-depth analyses. In order to aggregate the environmental impacts for an intuitively comparable set, these were weighted in order to convert the impacts into monetary values with common units. Ahlroth et al. [36] discussed the feasibility of evaluating the economic value of environmental impacts in a whole-life perspective. They proposed that one way to include external environmental costs in LCC (life-cycle costing) is to use monetary-weighted results obtained from environmental system analysis (such as LCA). There are several examples of such applications available in the literature. For instance, in the studies of Carlsson [37], Nakamura and Kondo [38], Kicherer et al. [39], Lim et al. [40] and Hunkeler et al. [41]. In this study, two monetary weighting systems, ecovalue08 with updated ecovalue12 weightings [36, 42, 43] and ecotax02 [44] were adopted and compared. The ecovalue monetary weighting set has been developed for evaluating mid-point environmental impacts based on willingness to pay, with a particular focus on Swedish conditions, while the ecotax set is based on environmental taxes and fees levied by the focal society [7]. Table 2 presents these two weighting sets.

2.4 Optimization Problem

In this study, the input variables consist of the dimensions of the bridge components and three concrete types. Concrete type, thickness of the slab in mid span (*Tf1*), thickness of the slab beside the haunches (*Tf2*), thickness of the frame legs beside foundations (*Tr1*), width of the haunches (*Bf1*), height

Table 1 Characterized environmental impacts.

Impact category*	Unit	Concrete C32/40 (m^3)	Concrete C35/45 (m^3)	Concrete C50/60 (m^3)	Reinforcement. (ton)
Global warming(GWP)	kg·CO_2·eq	344.505	352.694	383.748	2387.489
Human toxicity(HTP)	kg·1.4-DB·eq	20.381	20.835	21.968	417.752
Photochemical oxidantformation (POFP)	kg·NMVOC	0.969	0.989	1.051	10.060
Terrestrial acidification (TAP)	kg·SO_2·eq	0.918	0.934	0.998	9.428
Marine eutrophication (MEP)	kg·N·eq	0.052	0.036	0.038	0.243
Marine ecotoxicity(METP)	kg·1.4-DB·eq	0.237	0.240	0.249	2.956

*The P in each acronym refers to potential.

Table 2 Characterized environmental impact categories and monetary values.

Environmental impact category	Acronym	Unit	Ecovalue (SEK)	Ecotax02 (SEK)
Global warming	GWP	kg·CO_2·eq	2.85	0.63
Human toxicity	HTP	kg·1.4-DB·eq	2.81	1.5
Photochemical oxidant formation	POFP	kg·NMVOC	16	156
Terrestrial acidification	TAP	kg·SO_2·eq	30	15
Marine eutrophication	MEP	kg·N·eq	90	12
Marine ecotoxicity	METP	kg·1.4-DB·eq	12	0.3

* One Swedish Krona (SEK) ≈ 0.11 Euro (€).

of haunches (*Hf1*), thickness of frame legs beside haunches (*Tr2*), thickness of wing walls beside frame legs (*Tw1*), and thickness of wing walls at the end (*Tw2*) were considered as independent input variables. Furthermore, instead of a detailed reinforcement pattern, the necessary reinforcement area in every mesh element of each part of the bridge was calculated in a separate program to fulfill the constraints; these were considered to be dependent variables. Using the required reinforcement amounts as the design variables for steel reinforcement instead of detailed reinforcement patterns, which is unnecessary especially in the first stages of the design process, will dramatically decrease the number of input variables and hence the algorithm convergence time. More information about this assumption has been stated in the previously published study of Yavari, Pacoste and Karoumi [4]. The bridge geometry was assumed to be symmetric, and the optimization was performed for the bridge deck, wing walls, and frame legs. Moreover, slipping, overturning, and soil capacity were taken into consideration. A 2D section of the bridge showing different variables and constant parameters is illustrated in Fig. 2.

2.5 Constraints

The constraints of the optimization model represent the design requirements according to the ULS (ultimate limit state), SLS (serviceability limit state), and fatigue control based on the established Eurocodes [45] and the Swedish annex for the design of bridges, TRVK Bro 11 [46]. The minimum necessary reinforcement, minimum spacing between steel bars, minimum and maximum thickness of each element and other constructability limitations based on the abovementioned standards were taken into account.

2.6 Objective Function

In this study, the associated environmental cost of concrete and the reinforcement of the bridge deck, frame legs, and wing walls were evaluated. Since the material for form working is usually rented and can be reused many times, the environmental impacts of form works are assumed to be negligible compared to the reinforcement and concrete and therefore excluded in the objective function. The objective function is presented in Eq. (1):

$$f(x) = EnvCost_{concrete} + anchorage\ factor \times EnvCost_{reinforcement} \quad (1)$$

$$EnvCost = \sum_{i=1}^{i=6} impact_i \times monetary_i$$

where:

EnvCost = total associated environmental cost of the six impact categories;

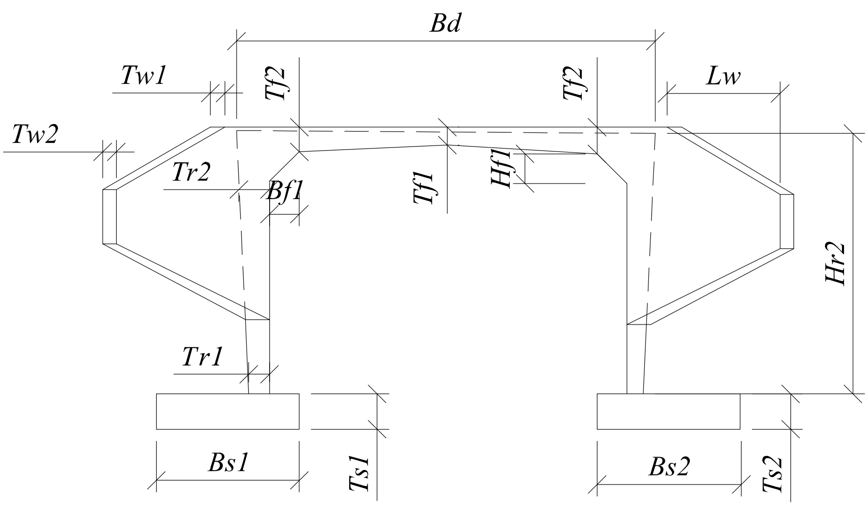

Fig. 2 Variables and constant parameters of a slab frame bridge [4].

$impact_i$ = *$impcat_i$* based on the characterized environmental impact categories (Table 1);

$monetary_i$ = associated environmental cost of *$impact_i$* based on the ecovalue or ecotax monetary weighting factors (Table 2);

anchorage factor = 1.4, for the consideration of extra reinforcements due to design details and anchorage length based on practical experience in design.

Lesser thicknesses of certain sections would require denser and higher amounts of reinforcements with smaller spacing between bars, resulting in greater construction time and labor and a more expensive structure. Thus, the thickness of the different elements was considered as an indicator of constructability and factored into the price of reinforcement work in the cost optimization. For the LCA optimization, the thicknesses of the different sections do not have any remarkable extra effect (i.e., additional environmental costs of concrete and reinforcement due to the thinner sections) on total environmental impacts and thus constructability factors were not considered in this study.

3. Results and Discussion

3.1 Case Study Application

As previously mentioned, the complete design automation and cost optimization processes were applied to evaluate several scenarios before a bridge was constructed [4]. The same methodology has been used in the present study. In this section, the results of the environmental impacts optimization of the present study are compared with those of the prior cost optimization. The case study is the Sadjemjoki Bridge, a road bridge located on road Number 941 in Norrbotten County in Sweden. The Sadjemjoki Bridge is an open foundation slab frame bridge with no deck skewness. The free opening of the bridge is 6 m; the total bridge length is 11.45 m. The free width is 7 m; the free height is 3.25 m. The bridge is symmetrical in both transversal and longitudinal directions. Thus, the input variables are presented for one frame leg and wing wall, and these are the same for the other frame leg and wing walls. Fig. 3 shows the sketch of the bridge. Design parameters and the considered loads and their corresponding values for the structural design of the bridge are presented in Table 3.

Table 4 summarizes the results obtained for the optimum variables and associated environmental costs based on the two monetary weighting systems. The stopping criterion which was fulfilled more quickly was the function tolerance, with a total calculation time of 9 hours. The results of the previous investment cost optimization as well as corresponding investment costs for the ecovalue and ecotax solutions based on the unit costs of the previous study are also presented. As can be seen, the optimum values of the two monetary weighting systems are exactly the same; the environmentally optimized models resulted in lower associated environmental costs (93,648 SEK in ecovalue and 39,520 SEK in ecotax) in comparison with the corresponding associated environmental cost when investment cost is the objective function (97,574 SEK in ecovalue and 42,350 SEK in ecotax). However, environmentally optimized models lead to higher investment costs (722,000 SEK) in comparison with the bridge that was previously found to be optimal solely based on investment cost (705,343 SEK). As previously mentioned, extra constructability factors due to thinner construction are not included in environmental optimization; consequently the environmentally optimized model indicated the use of concrete of a higher capacity to decrease the amount of concrete, thus leading to the use of thinner elements. Ultimately, the designers preferred an economical solution (in which investment cost was the objective function) due to considerations related to the constructability factors. The differences in the results of cost optimization and environmental optimization highlight the importance of integrating multiple criteria in structural designs. In future research, a methodology

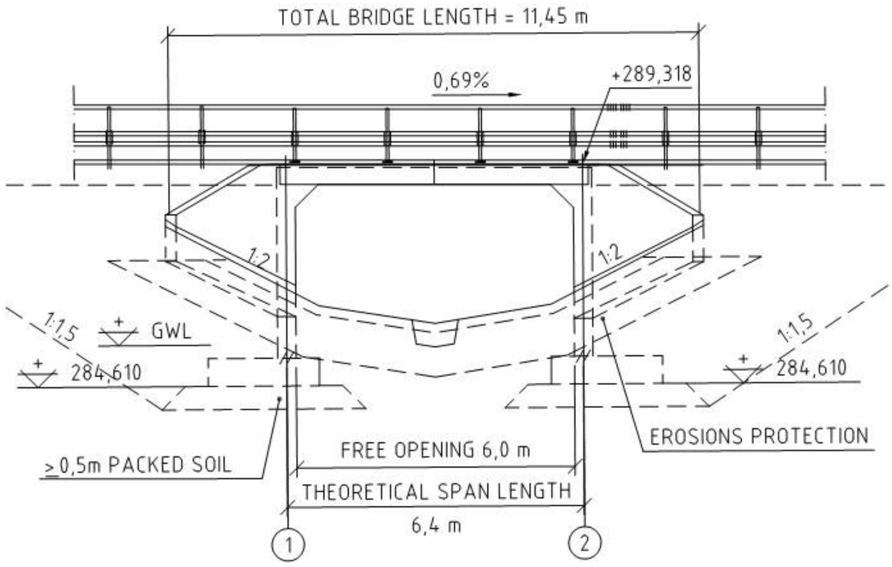

Fig. 3 Sketch of the Sadjemjoki Bridge [4].

Table 3 Design parameters and load assumptions [4].

Design and load assumptions	
Reinforcement type	B500B
Foundation	0.5 m packed soil, modeled as springs
Safety class	2
Life time	80 years
Exposure class	XD1/XF4 except upper side deck: XD3/XF4
Dead weight	$\gamma_{concrete}$ =25 kN/m^3
Overburden	$\gamma_{soil,dry}$ = 18kN/m^3, $\gamma_{soil,wet}$ = 11kN/m^3
Average ground water level	H_w = 0.9 m above foundation lower side
Surfacing	$Q_{surfacing}$ = 1.75kN/m^2
Even increase in temperature	ΔT = 31°, creep ratio = 0.28
Even decrease in temperature	ΔT = -41°, creep ratio = 0.28
Uneven increase in temperature	T_{max} = 6.6°, T_{min} = -6.6°, creep ratio = 0.28
Uneven decrease in temperature	T_{max} = 4°, T_{min} = -4°, creep ratio = 0.28
Shrinkage	Applied as decrease in temperature by 25°, creep ratio = 1.5
Road traffic load	Load Models 1 and 2 and classification traffic vehicles
Surcharge	P = 20 kN/m^2, k_0 = 0.34, rectangular constant distribution
Earth pressure	k_0 = 0.39, γ_{dry} = 18 kN/m^3, γ_{wet} = 11 kN/m^3
Braking force	Total force = 255 kN, imposed on the whole deck
Traffic lateral force	Total force = 64 kN, imposed on the whole deck
Support yielding	Vertical and horizontal on each support, 0.01 m
Guardrail load	Linear load magnitude on each edge beam: 0.5 kN/m
Wind load on traffic	Traffic profile height = 2.6 m, load pressure: 1.3 kN/m^2
Wind load on structure	Imposed structure height = 1.8 m, load pressure: 1.2 kN/m^2
Resistant earth pressure	Applied on frame legs
Fatigue load cycle	50,000; Average daily traffic in a year: 5,000

Table 4 Summary of the results.

Objective function	*Tf1* (m)	*Tf2* (m)	*Tr1* (m)	*Tr2* (m)	*Hf1* (m)	*Bf1* (m)	*Tw1* (m)	*Tw2* (m)	Concrete type	Investment cost (SEK)	Ecov. (SEK)	Ecotax (SEK)
Ecovalue	0.38	0.38	0.38	0.45	0.65	0.15	0.30	0.30	C50/60	722,000	93,648	39,520
Ecotax	0.38	0.38	0.38	0.45	0.65	0.15	0.30	0.30	C50/60	722,000	93,648	39,520
Investment cost	0.40	0.40	0.40	0.40	0.50	0.50	0.30	0.30	C35/45	705,343	97,574	42,350

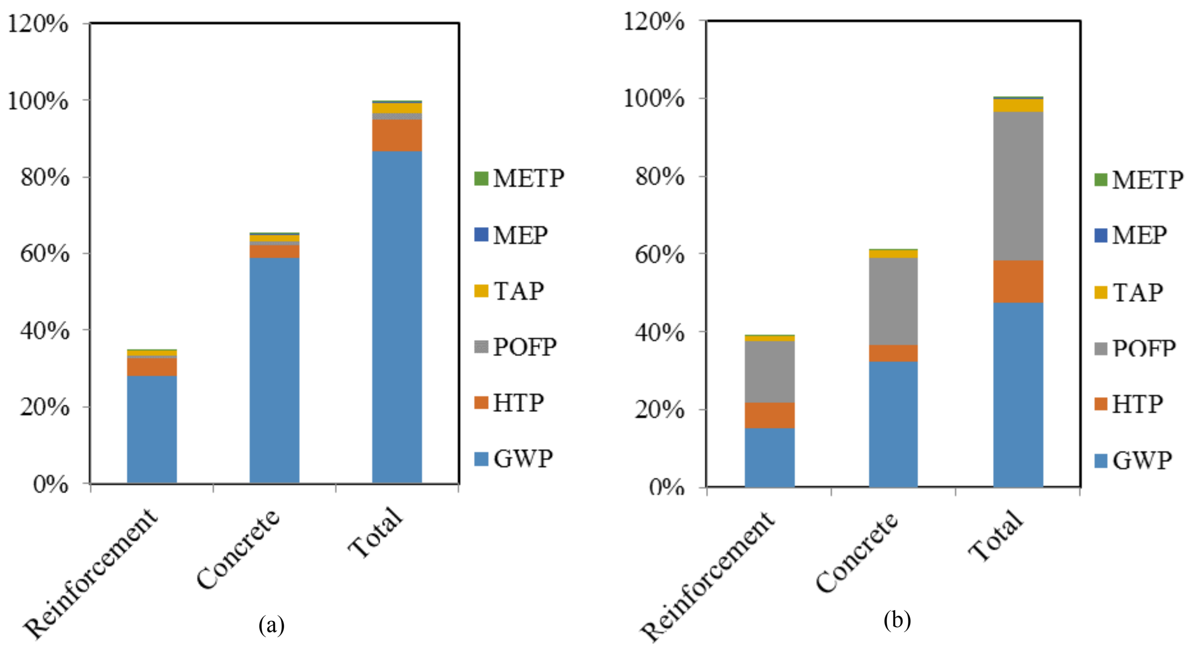

Fig. 4 Environmental impacts of the environmentally-optimized bridge based on: (a) ecovalue monetary system; (b) ecotax monetary system.

that would combine environmental impacts and investment cost is under investigation by the present authors. Both criteria should be considered to determine more sustainable, material-efficient, economical and time-effective bridge solutions.

Fig. 4 shows the associated environmental costs related to the environmental impacts of the environmentally-optimum bridge in different impact categories based on ecovalue and ecotax monetary systems. In both weighting systems, the concrete makes the greatest contribution toward environmental costs, rather than the reinforcement, representing 65% of the impact in ecovalue system and 61% in the ecotax system.

In both weighting systems, GWP gives the highest contribution toward the total associated environmental cost, up to 87% of the cost in ecovalue system and 47% of the cost in the ecotax system. HTP in the ecovalue represents the second highest contribution of nearly 8.3%, while this value is 10.9% in the in ecotax system, representing the third highest contribution. In this latter system, the second highest contributor at 38.2% of the total impact is POFP, while this value is only 1.6% in the ecovalue system. The other three impact categories (TAP, MEP and METP) contribute less than 4% in both weighting systems.

4. Conclusions

In this study, the environmental impacts optimization of concrete slab frame bridges was performed using the ReCiPe method and two monetary weighting systems. The environmental optimization was compared to the cost optimization of the same case study performed in the previously published study of

Yavari, Pacoste and Karoumi [4]. In summary, the following conclusions can be presented:

Structural optimization considering environmental impacts and their associated environmental costs was able to be efficiently implemented and applied in the design process of slab frame bridges.

Optimization based on the ecovalue and ecotax, two applied monetary weighting systems, led to the same results.

Optimization based on environmental impacts led to thinner concrete sections using a higher class of concrete; meanwhile, the cost optimization considered constructability factors and provided thicker sections and easier to construct design.

The designers preferred the economical solution due to the considered constructability factors; however, a multi-objective optimization that considers both environmental impacts and investment cost simultaneously is necessary in order to obtain more sustainable designs in the future.

Moreover, in future research, a sensitivity analysis should also be performed to examine the impact of the different variables on the results. An integrated optimization that would consider both investment and environmental costs for other bridge types such as beam bridges is also a part of the ongoing research of the present authors.

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Parameters That Influence Buckling Forces of a Fully Embedded Pile Based on the Finite Difference Method

Vlora Shatri[1], Luljeta Bozo[2], Bajram Shefkiu[1] and Burbuqe Shatri[1]

1. Department of Civil Engineering, Faculty of Civil Engineering and Architecture, University of Pristina, Pristina 10000, Kosovo;

2. Department of Urban Planning and Environment Management, University of Polis, Tirana 1005, Albania

Abstract: This paper work aims to present the effect of the soil stiffness (k), boundary conditions of piles and embedded length of piles (L) on a buckling force of a fully embedded pile and subject to an axial compression force only, based on the finite difference method. Based on this method, MATLAB software is used to calculate the buckling forces of piles. Effect of the soil stiffness (k), boundary conditions of piles and embedded length of piles (L) on a buckling force have been studied for reinforced concrete pile, whereas the modulus of horizontal subgrade reaction is adopted constantly with depth, increasing linearly with depth with zero value at the surface and increasing linearly with depth with nonzero value at the surface.

Key words: Finite difference method, pile, pile buckling force, buckling modal shapes.

1. Introduction

"Buckling" phenomena, by many authors is described as an unsustainability of an ideally straight column subject to an axial force exceeding a certain value.

Bifurcation is a field of linear analysis where determination of critical force of an ideal system is based on a solution of a standard problem of eigen value. The smallest eigen value determines the level of load up to which the system—the pile is stable, where as the respective eigen vector represents an equilibrium type of a pile.

Aiming to calculate the response of a vertical pile fully embedded on ground and subject to an external axial force, the pile shall be treated as a beam of an elastic foundation.

2. Buckling Force of a Fully Embedded Pile According to Finite Difference Method

Equation of the buckled pile subject to an axial load is:

$$E \cdot I \cdot \frac{d^4 y}{dx^4} + P \cdot \frac{d^2 y}{dx^2} + k_h \cdot y = 0 \tag{1}$$

where:

EI—pile stiffness;

P—pile axial force;

$k_h = k_0 + n_h \cdot x$—modulus of horizontal subgrade reaction approach by Ref. [4];

n_h—constant of horizontal subgrade reaction.

Based on the finite difference method, the solution of Eq. (1) can be obtained using the differential formulae. This method is a numerical technique that is used to solve the differential equations determining so the approximate solution only and the derivative of a function at a certain point may be approximated with an algebraic expression consisting of the values of that function in that point as well as of several adjacent points, meaning that through this method, the differential equation is transformed into an algebraic equation. The application of this method in solving buckling of piles has been discussed in Refs. [1, 3].

If the pile is divided into n nodes (1, 2, 3, …, $m-1$, $m+1$, …, n), and $n-1$ equal segments, Fig. 1, then based on the finite difference method, for the point m of the pile the following could be written:

Corresponding author: Burbuqe Shatri, Ph.D.; research fields: structural engineering. E-mail: bshatri@gmail.com.

$$P\left(\frac{d^2y}{dx^2}\right)_m = \left[P\left(y_{m-1}-2y_m+y_{m+1}\right)\right]\frac{1}{h^2} \qquad (2)$$

$$\left(\frac{d^2M}{dx^2}\right)_m = \begin{bmatrix} y_{m-2}E_{m-1}I_{m-1}+ \\ y_{m-1}\left(-2E_mI_m-2E_{m-1}I_{m-1}\right)+ \\ y_m\left(4E_mI_m+E_{m-1}I_{m-1}+E_{m+1}I_{m+1}\right)+ \\ +y_{m+1}\left(-2E_mI_m-2E_{m+1}I_{m+1}\right) \\ +y_{m+2}E_{m+1}I_{m+1} \end{bmatrix}\frac{1}{h^4} \qquad (3)$$

For a certain point m, n_h may be expressed as $n_h{\cdot}x = n_h{\cdot}(m-1){\cdot}h$, where n is the number of the nodes on a pile, $h = L/(n-1)$ and P are considered to be constant along the entire pile length L, than the Eq. (1) based on the finite difference method may be formulated as follows:

$$\begin{gathered} y_{m-2}E_{m-1}I_{m-1}+ \\ +y_{m-1}\left(Ph^2-2E_mI_m-2E_{m-1}I_{m-1}\right)+ \\ +y_m\begin{pmatrix} 4E_mI_m+E_{m-1}I_{m-1}+ \\ E_{m+1}I_{m+1}-2Ph^2+k_0h^4+n_h(m-1)h^5 \end{pmatrix}+ \\ +y_{m+1}\left(-2E_mI_m-2E_{m+1}I_{m+1}+Ph^2\right)+ \\ +y_{m+2}E_{m+1}I_{m+1}=0 \end{gathered} \qquad (4)$$

If adopted along the pile length, $E_mI_m = E_{m-1}I_{m-1} = E_{m+1}I_{m+1} = EI$, then Eq. (4) will become of this form:

$$\begin{aligned} &EI\left(y_{m-2}-4y_{m-1}+6y_m-4y_{m+1}+y_{m+2}\right)+ \\ &Ph^2\left(y_{m-1}-2y_m+y_{m+1}\right)+ \\ &k_0h^4y_m+n_h(m-1)h^5y_m=0 \end{aligned} \qquad (5)$$

where, y_m is the lateral displacement of the node m. Eq. (5) may be written as follows:

$$\begin{aligned} &\frac{P\cdot L^2}{EI\cdot(n-1)^2}\left(y_{m-1}-2y_m+y_{m+1}\right)=y_{m-2}-4y_{m-1}+ \\ &+\left(6+\frac{k_{hm}\cdot L^4}{EI\cdot(n-1)^4}+\frac{n_h\cdot L^5\cdot(m-1)}{EI\cdot(n-1)^5}\right)y_m- \\ &-4y_{m+1}+y_{m+2} \end{aligned} \qquad (6)$$

For the nodes from 1 to n, as the divisions on a pile, n-equations may be formulated. To resolve these n-equations, four additional equations are deemed necessary that means that "n + 4" equations are required in total. These four equations represent the two end restrain conditions at the tip and at the top of a pile.

The boundary conditions of the head of the pile based on the finite difference method may be expressed as follows [5]:

If the horizontal displacement at the pile head is limited,

$$y_0 = 0 \qquad (7)$$

If the rotation is limited,

$$\left(\frac{dy}{dx}\right)_{x=0} = 0 \Rightarrow \frac{y_1-y_{-1}}{2h} = 0 \Rightarrow y_1-y_{-1}=0 \qquad (8)$$

If the pile head is released from horizontal restraining, then the shear force perpendicular to the axis of the pile will be totally balanced with transverse component of the axial force P applied as follows:

$$(V)_{x=0}+P(\theta)_{x=0}=0 \Rightarrow EI\left(\frac{d^3y}{dx^3}\right)_{x=0}+P\left(\frac{dy}{dx}\right)_{x=0}=0$$

$$\Rightarrow EI\frac{y_2-2y_1+2y_{-1}-y_{-2}}{2h^3}+P\frac{y_1-y_{-1}}{2h}=0$$

$$\Rightarrow (y_2-2y_1+2y_{-1}-y_{-2})+\frac{PL^2}{EI(n-1)^2}(y_1-y_{-1})=0 \qquad (9)$$

If the pile head is released from the restrain in rotation then the moment is zero,

$$M=EI\left(\frac{d^2y}{dx^2}\right)_{x=0}=0 \Rightarrow EI\frac{y_1-2y_0+y_{-1}}{h^2}=0$$

$$\Rightarrow y_1-2y_0+y_{-1}=0 \qquad (10)$$

For the spring support of stiffness k_v with the possibility of horizontal displacement:

$$\begin{gathered} (V)_{x=0}+P(\theta)_{x=0}=k_v\cdot y \Rightarrow \\ EI\cdot\left(\frac{d^3y}{dx^3}\right)_{x=0}+P\cdot\left(\frac{dy}{dx}\right)_{x=0}=k_v\cdot y \\ \Rightarrow \frac{EI}{P\cdot L^2}n^2\cdot\left(y_2-2y_1+2y_{-1}-y_{-2}\right)+ \\ +\left(y_1-y_{-1}\right)-\frac{k_v\cdot L}{P\cdot n}y_0=0 \end{gathered} \qquad (11)$$

For the spring support of stiffness k_Θ with the possibility to rotate:

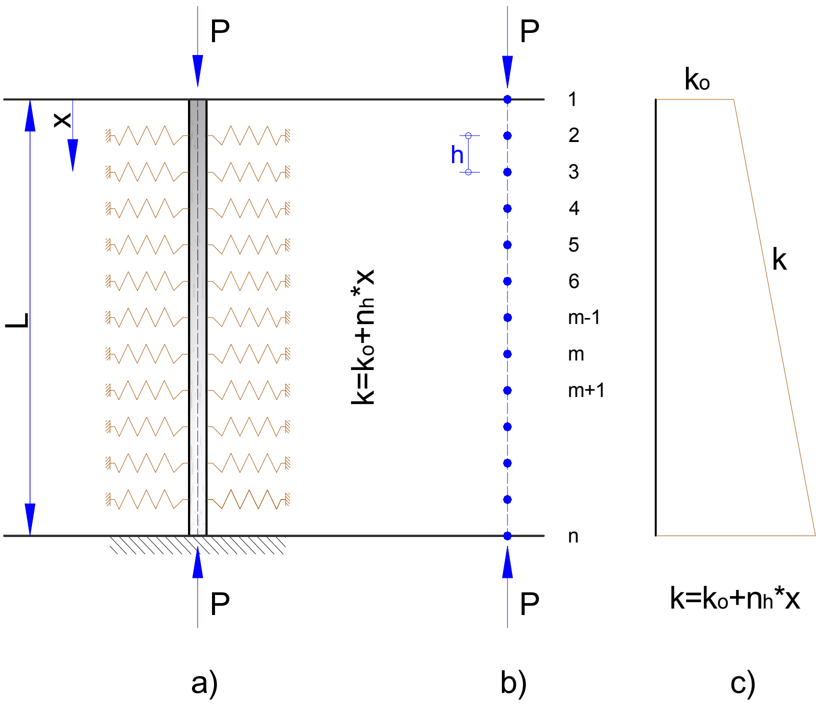

Fig. 1 Model of a pile based on the method of finite differences: (a) a pile pinned at the tip and pinned at the top (p-p); (b) division of the pile in "*n*" nodes; (c) modulus of horizontal subgrade reactions $k = k_0 + n_h{\cdot}x$.

$$M = EI \cdot \left(\frac{d^2 y}{dx^2}\right)_{x=0} = k_\theta \cdot \left(\frac{dy}{dx}\right)_{x=0} = 0$$

$$\Rightarrow \frac{EI}{k_\theta \cdot L}(y_1 - 2y_0 - y_{-1}) - (y_1 - y_{-1}) = 0 \quad (12)$$

Then Eq. (6) written for each and every node of a pile together with four equations of the boundary conditions of a pile, may be expressed in matrix shape and as follows:

$$[A]\{y\} + \frac{P \cdot L^2}{EI \cdot (n-1)^2}[B]\{y\} = 0 \quad (13)$$

Eq. (13) may be written as follows:

$$[A]\{y\} + \lambda[B]\{y\} = 0 \quad (14)$$

For calculation of the buckling force of the pile, the problem is turned into a problem for calculating the eigen values of matrix equation:

$$[A + \lambda B] = 0 \quad (15)$$

Therefore, det$|A + \lambda B| = 0$ can be used to determine λ.

The eigen values of the problem are:

$$\lambda = \frac{PL^2}{EI(n-1)^2} \quad (16)$$

These eigen values may be determined through various mathematical software. In this paper, all calculations are done with the software MATLAB. Critical buckling force of a pile will be the one of the lowest value:

$$P_k = \lambda \cdot EI \cdot (n-1)^2 / L^2 \quad (17)$$

To determine the buckling length of the pile, the Euler's force for the pile of elastic material, P_E, is equated with the critical buckling force of the pile:

$$\pi^2 EI / (\alpha L)^2 = \lambda \cdot EI \cdot (n-1)^2 / L^2 \quad (18)$$

$$\alpha = \pi / \sqrt{\lambda} \cdot (n-1) \quad (19)$$

where:

α—the ratio between the equivalent buckling length of the pile, L_0 and the pile length, L.

2.1 Buckling Force of a Fully Embedded Pile, Pinned at the Head and Pinned at the Tip (p-p)

For cases considered in this paper, a reinforced concrete pile of a diameter D = 0.3 m and concrete class C25/30 is adopted. A constant axial load along the pile length is assumed and the initially straight pile axis.

The members of the matrixes [***A***] and [***B***] based on the finite difference method [6], for the case of fully embedded pile, pinned at the head and pinned at the tip (p-p) and a linear variation of soil stiffness, $k = k_o + n_h \cdot x$, (Fig. 1) (as by the software MATLAB) are:

Number of segments

for (n – 1)

A = zeros (n + 4, n + 4);

A(1, 3) = 1;

A(2, 2) = 1; ***A***(2, 3) = –2; ***A***(2, 4) = 1;

A(n + 3, n + 3) = 1; ***A***(n + 3, n + 2) = –2; ***A***(n + 3, n + 1) = 1;

A(n + 4, n + 2) = 1;

for i = 1:n

A(i + 2, i + 2 – 2) = 1; ***A***(i + 2, i + 2 – 1) = –4;

A(i + 2, i + 2 – 0) = 6 + (k_0*L^4)/(E*I*(n – 1)^4) + (n_h*L^5*(i – 1))/(E*I*(n – 1)^5); ***A***(i + 2, i + 2 + 1) = –4; ***A***(i + 2, i + 2 + 2) = 1;

end

B = zeros(n + 4, n + 4);

for i = 1:n

B(i + 2, i + 2 – 1) = 1; ***B***(i + 2, i + 2 – 0) = –2; ***B***(i + 2, i + 2 + 1) = 1;

end

In Fig. 2, the relationship between the buckling force of a pile (p-p) and its length (L) is given, for the case when modulus of horizontal subgrade reaction is constant along the pile length, $k_h = k_0$ = 1,000 kN/m^2. The pile (p-p) is deformed in a form of half a wave of a sine curve, of a number of waves dependent on the total pile length. With an increase of the pile length (L), the buckling force becomes normalized to a P_k = 6,955 kN, and due to lateral restrains caused by the surrounding soils of the pile, this force is always greater than buckling force of a column (p-p) made of elastic material—the Euler's force $P_E = EI \cdot \pi^2/L^2$.

The diagram of the buckling force P_{cr}, depending on the pile length (L), for the case of a pile of stiffness and end conditions, same as of the above mentioned case (p-p) but with the modulus of horizontal subgrade reaction that linearly increases with depth, from nonzero value at the surface, k_0 = 1,000 kN/m^2 and n_h = 1,000 kN/m^3, are given in Fig. 3. With an increase of the pile length (L), the buckling force of fully embedded pile (p-p), converges to the value P_k = 1.432*10^4 kN, that is approximately twice greater as the buckling force of the fully embedded pile (p-p) of a constant modulus of horizontal subgrade reaction in

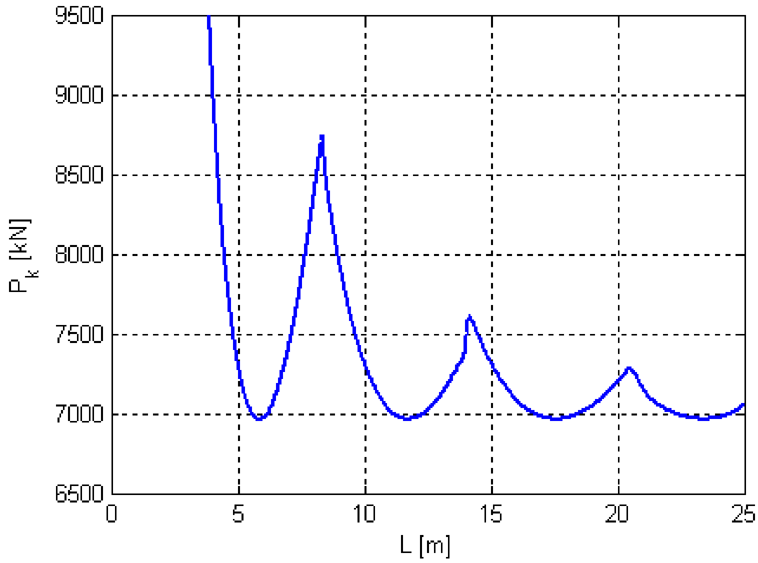

Fig. 2 Buckling force for pinned-pinned end conditions of a pile (p-p) of a diameter *D* = 0.3 m, concrete class C25/30, length *L*, and when modulus of horizontal subgrade reaction k_0 = 1,000 kN/m^2 (as obtained by MATLAB).

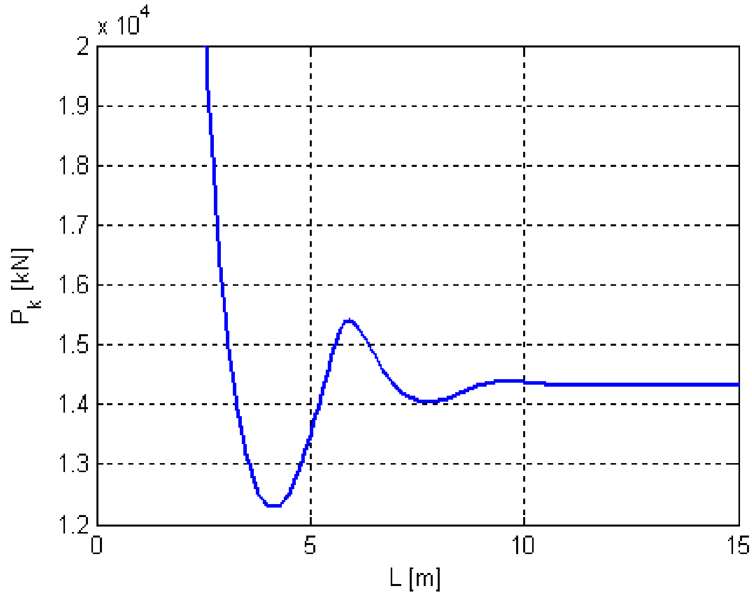

Fig. 3 Buckling force for pinned-pinned end conditions of a pile (p-p), of a diameter D = 0.3 m, concrete class C25/30, length L, and soil stiffness, k = 1,000 kN/m^2 and n_h = 1,000 kN/m^3 (as obtained by MATLAB).

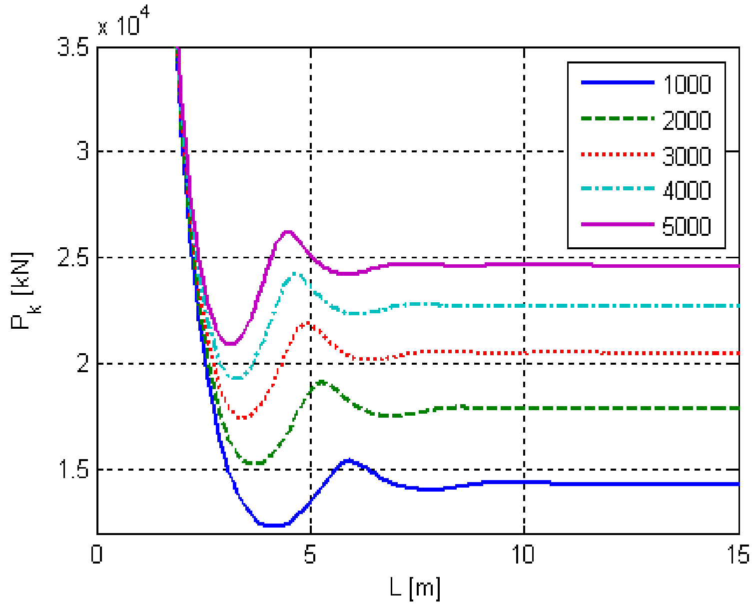

Fig. 4 Buckling forces for a pinned-pinned end conditions of a pile (p-p), of diameter diameter D = 0.3 m, concrete class C25/30, length L, when k_0 = 1,000 kN/m^2 and n_h = 1,000, 2,000, 3,000, 4,000, 5,000 kN/m^3 (as obtained by MATLAB).

depth ($k_h = k_0$ = 1,000 kN/m^2 and P_k = 6,955 kN). In this case also, the pile deforms in a mode of a half wave of a sine curve, with a number of waves depending on the total length of the pile.

The effect of increasing "n_h" values on a buckling force of the pile (p-p) when "k_0" is kept constant, is given in Fig. 4. A fully embedded pile (p-p) in soil of k_0 = 1,000 kN/m^2 and n_h different from 1,000 to 5,000 kN/m^2, is adopted for analysis. It is observed in Fig. 4, buckling modes are varying between as the pile length increases, as well as an increase of a buckling force as the n_h value increase.

In Fig. 5, through spatial diagrams of buckling forces P_k as a function of pile length L, the effect of the increase of the values of the modulus of horizontal subgrade reaction, k_0, is given, on a pile buckling force when the constant of horizontal subgrade reaction is kept constant, (n_h = constant). The constant of horizontal subgrade reaction is adopted n_h = 1,000 kN/m^3 whereas the modulus of horizontal subgrade reaction "k_0" increasing from 1,000 to 5,000 kN/m^2.

As in the previous case, buckling load P_k increases with an increase of "k_0" while "n_h" remains constant and the fundamental buckling mode shapes change with an increase of pile length (Figs. 6-9).

Comparing the given diagrams in Fig. 4 with those in Fig. 5, conclusion can be drawn that values of pile buckling forces (p-p), are higher for the cases when k_0 = constant and n_h changing comparing to cases n_h = constant and k_0 changing.

Buckling length of a pile (p-p), diameter D = 0.3 m,

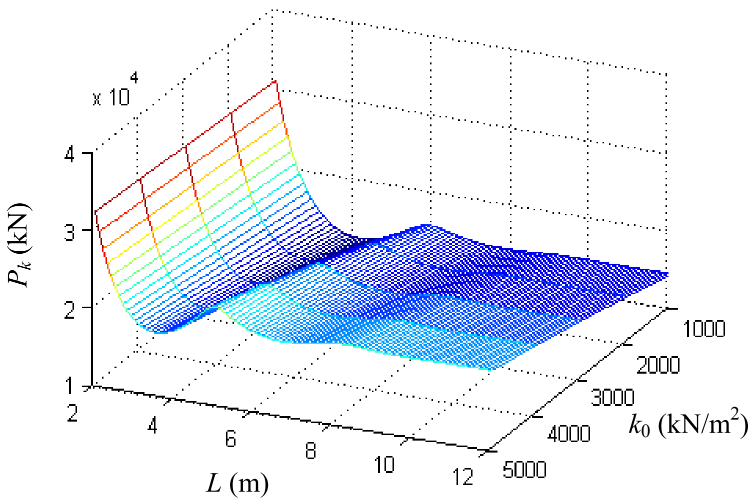

Fig. 5 Buckling forces for a pinned-pinned end conditions of a pile (p-p) of diameter D = 0.3 m, concrete class C25/30, length L, when k_0 = 1,000, 2,000, 3,000, 4,000 and 5,000 kN/m^3 and n_h = 1,000 kN/m^3 (as obtained by MATLAB).

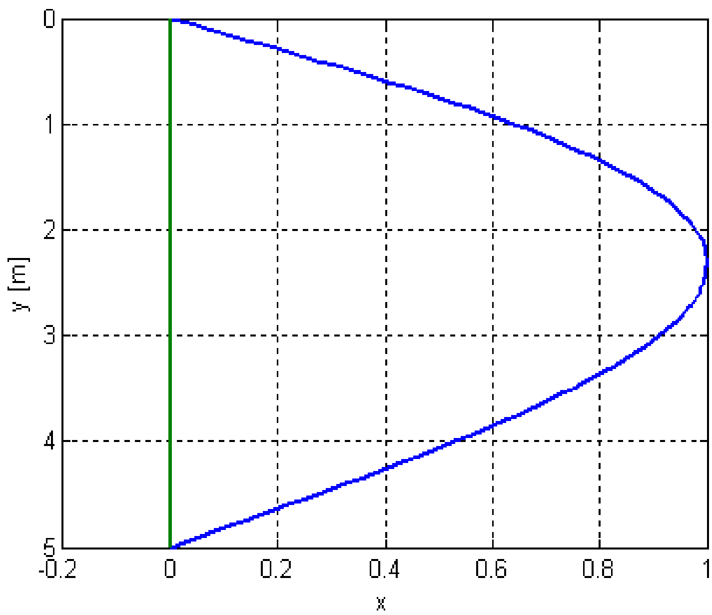

Fig. 6 Fundamental buckling mode shape of the fully embedded pile (p-p), of diameter D = 0.3 m, concrete class C25/30 for n_h = 1,000 kN/m^3 and pile length L = 5 m (as obtained by MATLAB).

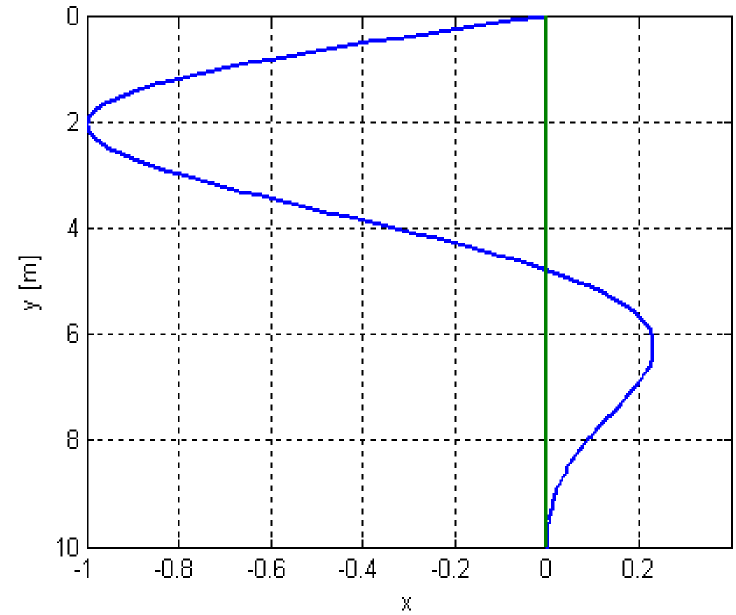

Fig. 7 Fundamental buckling mode shape of the fully embedded pile pinned top-pinned tip, of diameter D = 0.3 m, concrete class C25/30, for n_h = 1,000 kN/m^3 and L = 10 m (as obtained with MATLAB).

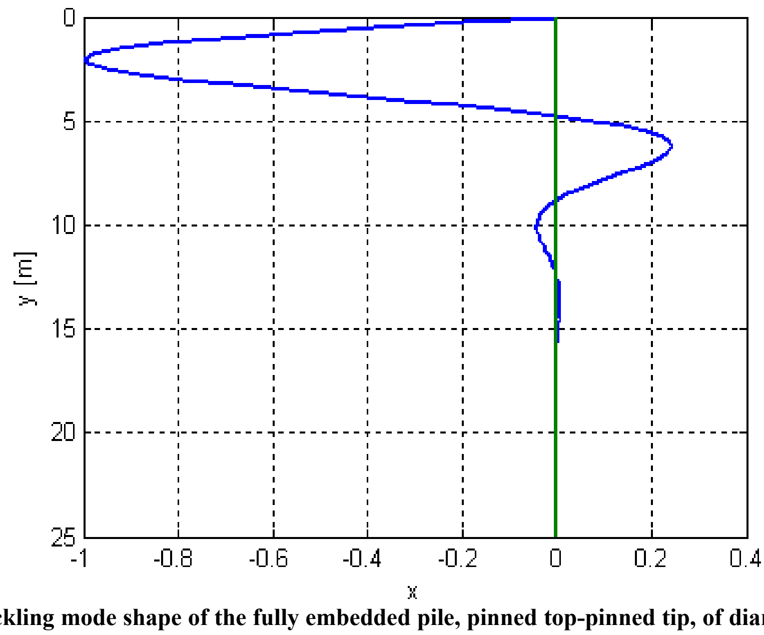

Fig. 8 Fundamental buckling mode shape of the fully embedded pile, pinned top-pinned tip, of diameter D = 0.3 m, concrete class C25/30, for n_h = 1,000 kN/m^3 and L = 25 m (as obtained by MATLAB).

length L = 25 m and concrete class C25/30, is smaller in case when the pile is fully embedded in ground of k_0 = 1,000 kN/m^2 and n_h = 25,000 kN/m^3 (Fig. 9) than when the same pile is embedded in ground of k_0 = 0.0kN/m^2 and n_h = 1,000 kN/m^3 (Fig. 8).

So, as stiffer the soil is, comparing with pile stiffness, the pile buckling length will be relatively smaller.

3. The Influence of the Boundary Conditions on the Buckling Force

To show the extent of the influence of the end conditions of a pile into a buckling force, a pile of diameter D = 0.3 m, concrete class C25/30, of length L, fully embedded on ground of the constant of horizontal subgrade reaction n_h = 200 kN/m^3 and the

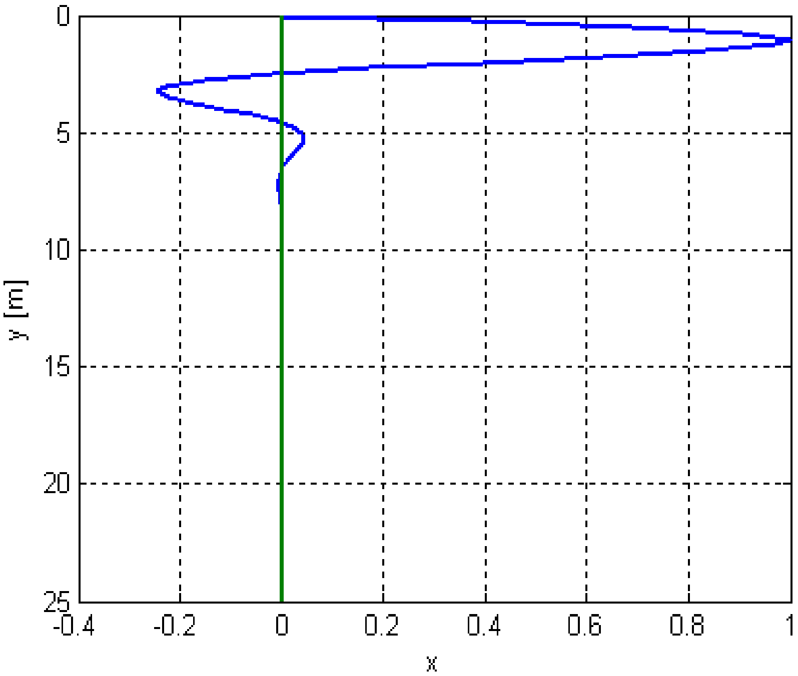

Fig. 9 Fundamental buckling mode shape of the fully embedded pile (p-p) of length L = 25 m, for k_0 = 1,000 kN/m^2 and n_h = 25,000 kN/m^3 (as obtained by MATLAB).

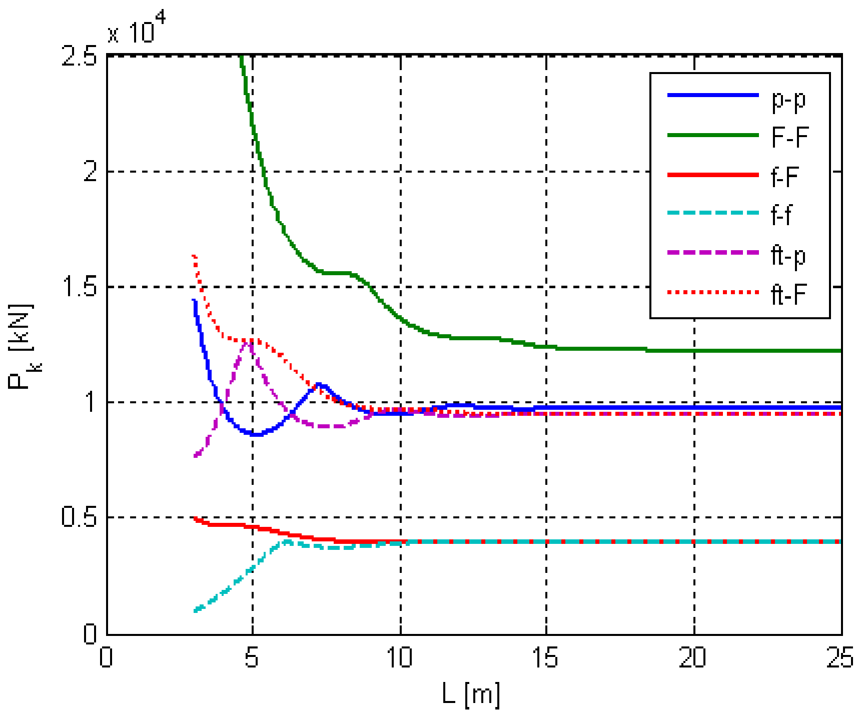

Fig. 10 The influence of end conditions to a buckling forces of a fully embedded pile with diameter D = 0.3 m, concrete class C25/30, length L, for modulus of horizontal subgrade reaction k_0 = 1,000 kN/m^2 and a constant of horizontal subgrade reaction n_h = 200 kN/m^3 (as obtained by MATLAB).

modulus of horizontal subgrade reaction k_0 = 1,000 kN/m^3, of the end conditions: pinned at the top—pinned at the tip (p-p), fixed at the top—fixed at the tip (F-F), free at the top—fixet at the (f-F), free at the top—free at the tip (f-f), fixed against rotation but free in translation top—pinned at the tip (ft-p), and fixed against rotation but free in translation—fixed at the tip (ft-F), are taken for consideration [2].

Referring to Fig. 10, depending on the values of buckling forces obtained, the piles are clasified into three groups:

(1) the first group—a pile (F-F);

(2) the second group—a pile (p-p), (ft-p) and (ft-F);

(3) the third group—a pile (f-f) and (f-F).

The maximum values of buckling forces are obtained for a pile of the end conditions fixed at the top—fixed at the tip (F-F), while the minimum values are obtained for the piles of the end conditions, (f-f) and (f-F). The buckling forces for piles (p-p, ft-p and ft-F) distinguish for the higher force values comparing to the forces for the piles (f-f and f-F), and smaller than for piles of end conditions (F-F).

From Fig. 10, the behavior of pile (f-F), length of $L \geq 10$ m, is the same as that of the type (f-f) since the buckling forces calculated with MATLAB for these two types of piles, based on the finite difference method, both converge to $P_k = 0.39 \times 10^4$ kN.

For the lengths $L > 10$ m, for the case of the pile (p-p) (Fig. 10), the buckling force converges to value of 0.97×10^4, while converging to 0.95×10^4 for the case of the piles (ft-p and ft-F). Since the difference in these values of buckling forces is only 2%, these two types of piles may be categorized in the same group.

As seen in Fig. 10, it may be also concluded that there is only the end condition of the head that influences the buckling force and not the end condition of the tip of the pile, as well as that with an increase of the pile length the buckling force of the pile remains unchanged.

4. Conclusions

The method for determination of the buckling forces of piles of different restraint conditions based on the method of finite differences is presented in this paper work. The software MATLAB is used to determine the forces by applying this method.

The pile buckling forces depend on the pile length L, on the pile stiffness EI, boundary conditions and on the geometric properties of soils. They increase with an increase of constant of horizontal subgrade reaction n_h, by keeping constant the modulus of horizontal subgrade reaction k_h, as well as in contrary, when modulus of horizontal subgrade reaction k_h is increased, while the constant of horizontal subgrade reaction n_h remains constant. For the case of piles of end conditions pinned at top—pinned at tip (p-p), higher values of buckling forces are obtained in cases when the constant of soil reaction n_h increases while the modulus of soil reaction k_h is kept unchanging.

The buckling force is maximal for the pile of the end conditions fixed-fixed (F-F) due to the increase of the restraint that offered by the fixed top and the fixed tip, and the force is minimal for the end conditions free-free (f-f) and free-fixed (f-F).

In the value of buckling force of a pile, only the end condition of the head of the pile is prevailing.

With an increase of the pile length, the buckling force remains unchanged.

The modal shapes of buckling of piles analysed with MATLAB software are influenced by pile length since they differ between with an increase of the length of the pile. The buckling mode changes from the first mode to the second and then to the third as the length of the pile increases.

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Improvement of Technological Solutions for Sheet Piling Walls Made of U-Shape Piles

Victor Petrosyan and Michael Doubrovsky
Sea, River Ports and Waterways Department, Odessa National Maritime University, Odessa 65029, Ukraine

Abstract: As it is evident from the practice of construction and maintenance of thin retaining walls, the degree of developing of frictional forces in interlock connections of steel sheet U-shape piles essentially influences the realization of the values of geometric characteristics of the piles cross-section (the moment of inertia and the section modulus) reduced to the length unit of the construction. The article offers new and simple solutions for realization and economically effective technological approaches to provide joint work of the sheet piles being considered, which improve the adequacy of design and reliability of maintenance of thin retaining walls.

Key words: Sheet piling walls, steel U-shape piles, interlock connections.

1. Introduction

A possibility of mutual displacements of adjacent steel U-shape piles in their interlock connections at the stage of the maintenance as the result of friction resistance deficit in the interlocks [1-4] is a drawback of traditional constructions of thin retaining walls. This can happen, for example, in case the wall bends under the perception of backfill soil active pressure (particularly, in the zone of maximal horizontal deflection of the wall).

Thus, due to the location of the U-shape sheet piles interlock connections on the neutral axis of the wall (or close to it), the actual values of major geometrical characteristics of the wall cross section, which influence the parameters of flexural rigidity of the construction, i.e., the moment of inertia and the section modulus, can be significantly lower. In some cases, this difference reaches 2-3 times against the corresponding values specified in the sheet piles manufacturers' catalogues. Such circumstance may decrease the reliability of the construction [1-3].

The values of geometric characteristics of the sheet pile wall, as specified in the catalogues of the sheet piles manufacturers and used by project designers and contractors, are defined using assumption of fixed sheet piles in their interlock connections in longitudinal direction. These values disregard possible mutual displacements of the piles in the interlocks. The above-mentioned constructions (for example, the front wall and the anchor wall of the berthing structure made of U-shape steel sheet piles) are shown in Figs. 1 and 2.

With the purpose of avoiding the above situation, the companies—manufacturers of steel rolled sheet piles, recommend using several approaches.

At the stage of manufacturing in factory conditions, the sheet piles can be combined into packages, 2-3 single sheet piles in each, connected by pressing or welding in the interlock connections (Fig. 3).

At the stage of performing works for construction or reconstruction (repair, strengthening, etc.) of sheet pile walls, it is recommended to weld the interlocks of adjacent piles. This approach as applied to berthing structures results in significant difficulties when performing welding jobs, making them time-consuming and expensive (specifically in underwater conditions or in the zones of variable elevation of water).

Corresponding author: Michael Doubrovsky, professor; research fields: maritime and port construction. E-mail: doubr@tm.odessa.ua.

Fig. 1 Berth front wall of a steel U-shape sheet piles.

Fig. 2 Anchor wall of a steel U-shape sheet piles.

Fig. 3 Package of two U-shape sheet piles connected in the interlocks by pressing in factory conditions.

In connection with the above, some improved engineering and technological solutions are presented in this article. They are aimed at the creation of reliable and efficient construction of sheet pile wall made of U-shape steel sheet piles with interlock connections located at the zone of the neutral axis of the wall.

2. The Use of Construction Elements Improving Joint Work of U-Shape Sheet Piles

In conformity with the suggested solution, the retaining wall is provided on the inside and outside with tiers of rigid straps distributed in longitudinal and vertical directions, which connect flanges of two or more piles. In this case, the straps connect only those piles that are located on the one side of the neutral axis of the construction, while the positions of the strip tiers height wise correspond to the zones of sheet piles maximum deflections.

The role of the straps consists in the prevention of mutual longitudinal displacement of adjacent piles. In such a case, the possibility of sheet piles slipping in interlock connections (irrespectively to the force of

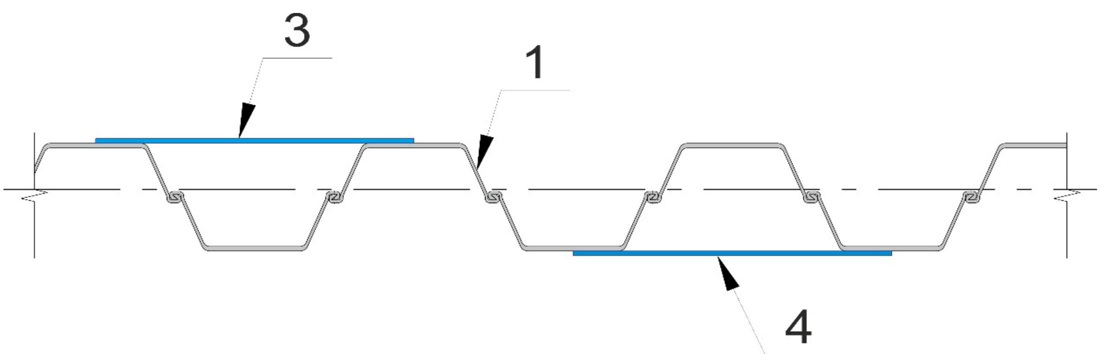

Fig. 4 Plan of the sheet pile wall.

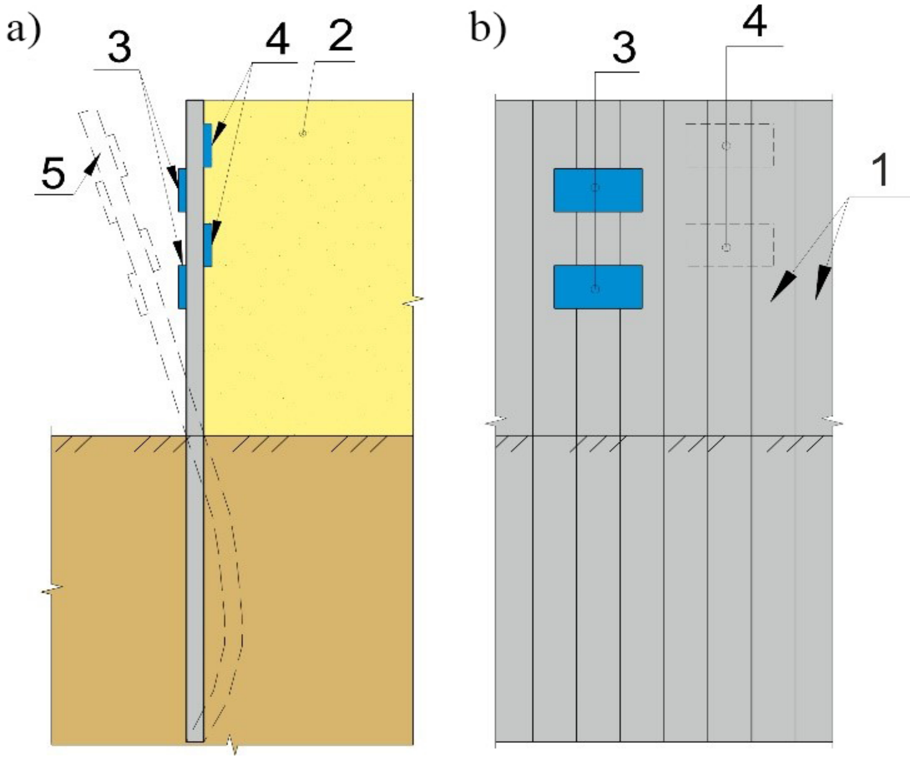

Fig. 5 Application of the rigid strips for the bulkhead: (a) cross-section; (b) and fragment of the sheet pile wall face.

friction in the connection) is excluded. Due to this approach, a rigid connection of sheet piles is ensured, which improves the efficiency and reliability of the construction in service (calculated and real values of both moment of inertia and section modulus are the same).

Fig. 4 shows the horizontal cross-section of the berthing structure construction at the level of one of the tiers of rigid straps; Fig. 5 shows the vertical cross-section and a fragment of the construction facade.

The sheet pile retaining wall (Figs. 4 and 5) includes steel U-shape sheet piles 1, driven in soil by the “interlock” method (the locks of sheet piles are located on the neutral axis of the wall) with backfill material 2 behind. Rigid straps (for example, of steel sheet) 3 and 4 are welded to the pile flanges on both sides in the form of tiers along the whole construction. Possible deformations of the construction under the influence of the backfill soil active pressure are shown in dotted lines and defined as position 5 (Fig. 5a).

The construction of steel sheet piles 1 being considered works as follows: under the influence of the backfill soil active pressure the front wall bends as a cantilevered beam driven in the soil at the lower end; as the result of the effect of the backfill active pressure 2, wall 1 will bend and its elastic axis will take position 5. At that, due to the rigidity of the straps, the adjacent piles will not slide in relation to each other in interlocking connections, ensuring thereby maximal (in conformity to manufacturers’ catalogues) values of characteristics of rigidity and geometry of cross sections of the berthing structure.

By varying the sizes of the straps and, consequently, the total length of the welding seam that fixes the plates by their perimeters to the piles flanges, and thus ensuring the connection of the mutual piles, it becomes possible to regulate the degree of free movement of the piles relative sliding in the interlock connections up to its complete elimination. In this way, the effectiveness of the straps welded to the sheet piles flanges can be essentially higher than that of the lap weld, which is made directly in the interlock connection of adjacent piles (because the length of the lap weld is limited by the corresponding length of the interlock connection of the mutual piles). For example, in the piles of European production of the type PU, the length of the lap weld around the perimeter of one strap according to the solution suggested can be 3-4 times as longer than the length of the lap weld in interlock connection at the level of the strap.

3. Improvement of Technological Solutions for U-Shape Sheet Pile Walls

In conformity with the solution suggested, the sheet piles in vertical plane intersect the neutral axis of the wall and the interlock connections of the piles are installed with a rake relative to the vertical. This allows ensuring a growth of friction force in the piles interlocks, which prevents mutual displacement of sheet piles in the connections and increases the degree of the construction work as a continuous structure, as well as its rigidity, reliability and effectiveness.

The solution of the task is ensured by the fact that each next pile of the sheet pile wall is placed over the interlock connection with the previous pile. Such positioning of the sheet piles in the berth wall allows transferring a part of the weight of the overlying pile to its interlock connection with the lower pile and thus increasing the friction force in the interlock, which prevents mutual displacement of the sheet piles in the interlocks.

Fig. 6 shows a plan of the sheet pile wall construction; Fig. 7—longitudinal cross-section of the construction; Fig. 8—the scheme of the effect of the overlying sheet pile on its interlock connection with the underlying pile.

The construction (Figs. 6 and 7) includes steel sheet piles 1, which are located in the foundation soil with piles interlock connections 2 located on the neutral axis 3, the piles being positioned with a tilt relative to the vertical.

The effective force of overlying pile on the interlock

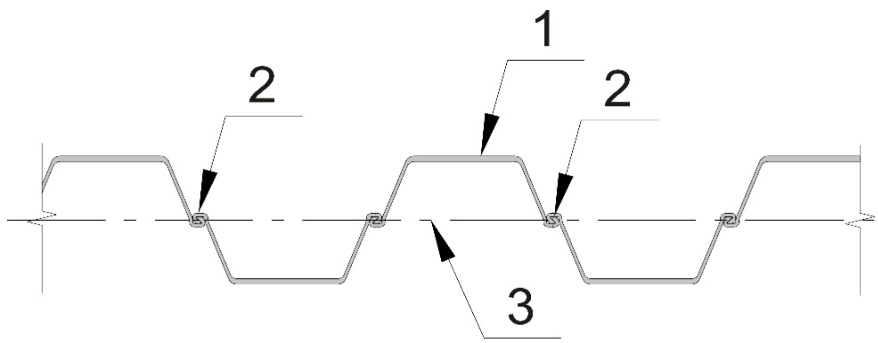

Fig. 6 Fragment of the sheet pile wall.

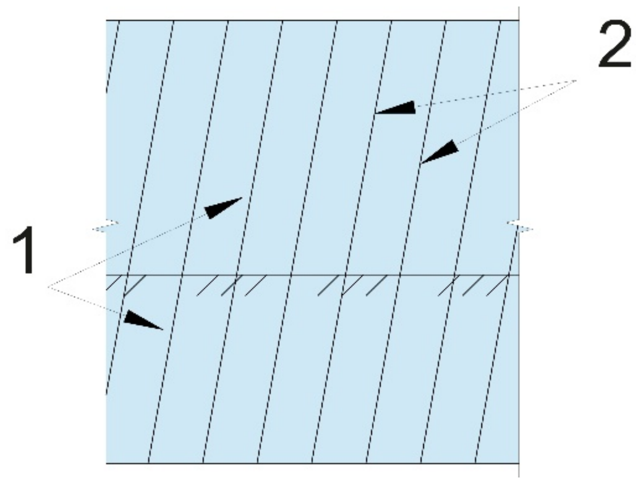

Fig. 7 Fragment of longitudinal cross-section of the sheet pile wall.

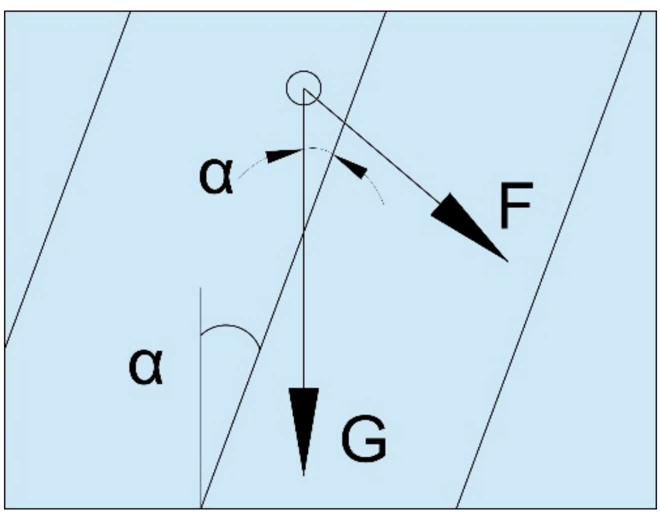

Fig. 8 Scheme of the effect of overlying pile on the interlock connection with the underlying pile.

connection with the underlying one is determined by the formula according to Fig. 8:

$$F = G \cdot \sin\alpha \tag{1}$$

where:

G—the resultant gravity of the overlying pile;

α—angle of the piles tilt to the vertical.

The force F, normal to the axis of the interlock connection, increases the frictional force, which appears at relative displacement of adjacent piles in the interlock connection and prevents sliding of one pile relative to the other in the interlock connection. Corresponding friction force increment in the interlock connection Δ_f, stipulated by the effect of the force F, will be equal to:

$$\Delta_f = F \cdot k_t \quad (2)$$

where, k_t—co-efficient of friction in the interlock connection of the sheet piles, to be determined experimentally for concrete soils, in which the sheet pile wall is being built and maintained [5, 6].

From the point of view of quantitative evaluation of the influence of the force F on the friction force increment in the interlock connection of sheet piles, the following is worth marking. Theoretically, maximal value of this force with fixed weight of sheet pile G according to Eq. (1) corresponds to angle α = 90°, i.e., to horizontal position of the sheet piles. Obviously, such position of sheet piles certainly disagrees with the constructive idea of the considered berthing structure (sheet piling wall).

Technical parameters of the equipment and mechanisms for driving of sheet piles during construction, reconstruction, repair or strengthening the structures being considered present a real limitation of angle α. The question is, for example, of drop hammer (diesel, hydraulic), pressing mechanisms (static, hydraulic) or vibro-hammers (electric, hydraulic), which can be either fixed to the heads of the piles being driven, or move on guide mast. In the last case, the angle of rake of the ram guides can make 4-5° to both sides.

At the value of resultant gravity of the overlying pile of standard (for European production) type G = 30 kN and the coefficient of friction k_t = 0.65, the use of Eqs. (1) and (2) allows determining friction force increment in the interlock connection of adjacent piles as Δ_f = 2.67 kN.

4. Conclusions

The engineering and technological solutions presented in this article have been elaborated based on quite simple and non-expensive approaches, namely:

- The provision of pairs or groups of piles having the same orientation relative to the neutral axis of the sheet pile wall with the uniting rigid straps;
- The provision for the tilt of sheet piles relative to the vertical in the longitudinal direction of the berthing structure.

The solutions offered ensure:

- more reliable integrity of adjacent sheet piles in the construction of a berthing structure;
- approach of actual values of sheet piling walls geometrical characteristics (inertia moment, section modulus) to their values in the catalogues offered by the manufacturers of steel rolled sheet piles;
- improvement of quality and effectiveness of design solutions;
- lowering the expenses for the maintenance of retaining sheet pile walls.

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Behaviour of Rendering Mortar for Rehabilitation of Buildings Subjected to Rising Damp

Paulo Cabana Guterres[1] and Luiz Pereira de Oliveira[2]

1. Civil Engineering College, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil;

2. Centre of Materials and Building Technologies, University of Beira Interior, Covilhã, Portugal

Abstract: This paper presents an experimental study on the behaviour of rendering mortars used to rehabilitate buildings subjected to rising damp and consequently affected by efflorescence. This study was initiated by the characterization, "in situ" and in laboratory, of rendering mortar used as walls coating of an old building affected by efflorescence. Temperature, superficial humidity, mortar water content and salts content were used as characterization tests. Taking into account the reconstitution of old building rendering mortar composition, four different proportions were proposed to simulate different mortars skeletons and porosities. The mortars binders were composed by cement and three additions, such as hydrated lime, artificial hydraulic lime and quicklime paste. The results of capillary water absorption, soluble salts content and permeability test on masonry panels allowed analyzing the performance of mortars compared to the susceptibility of water rise and formation of salts. From this analysis, it was possible to draw some practical recommendations for design coating repair mortar in buildings subject to the problem of rising damp.

Key words: rehabilitation, rendering mortar, rising damp, capillarity, water permeability, soluble salts.

1. Introduction

A survey of the buildings conservation status belonging to the central perimeter of Pelotas city, Rio Grande do Sul State, Brazil, according Paladini criteria [1], shows that almost half of the facades, i.e., 189 facades (44.6%) have a good condition of conservation. Very good condition is identified in 66 (15.6%) facades, in steady state are 156 (36.8%) facades and in bad state are 13 facades (3.1%). These facades have been shown from 0 to 1 typical anomalies distributed asymmetrically, where 212 (50.0%) facades had 3 or more anomalies. From the identified deficiencies, the results show that the rising damp corresponds to 17.2% of the anomalies.

Temperature and surface humidity measurements on the old buildings walls were held in 2000, in different periods (May, June and July) and always in the same time band. The results showed average values of 15 °C ± 1 °C and 75% ± 4% RH (relative humidity). Rendering mortar samples extracted from the buildings walls were characterized in terms of components and proportions, it has been determined that these mortars were constituted of lime (quicklime) and natural sand from Arroio Pelotas with various mass proportions as: 1:4, 1:5, 1:6 and 1:12.

In this study, an experimental plan was designed to evaluate the mortars susceptibility to rising damp action, to transport soluble salts and to develop anomalies by efflorescence and/or crypto-efflorescence.

2. Experimental Program

The reconstitution of rendering mortars from the buildings walls of the historic center of Pelotas enables to define a reference mortar and a cement based mortars incorporating three types of lime: quicklime, hydrated lime and artificial hydraulic lime. The materials used in mortars were selected in view of its technical characteristics and availability in the domestic market, giving emphasis to those of traditional use and facility to obtain in Pelotas city.

Corresponding author: Paulo Cabana Guterres, professor, dr.; research fields: construction materials. E-mail: prcguterres@gmail.com, paulo.guterres@ufu.br.

2.1 Materials

A pozzolanic Portland cement CP IV 32, according to NBR 5736/1991 [2], with a density 2,700 kg/m^3 and Blaine fineness of 416 m^2/kg was used. An hydrated lime with density 0.553 kg/m^3, an artificial hydraulic lime incorporating rice husk ash with density 0.644 kg/m^3 and a quicklime (non hydrated) with density 0.913 kg/m^3 were used as additions. The sand used in this study was selected in manner to simulate the best sand identified in mortar reconstitution process applied in the original render of some of the buildings in the historic centre of Pelotas. The selected sand was natural river sand from the Arroio Pelotas with low impurities content, with density 1,484 kg/m^3, maximum size 4.8 mm and fineness modulus 2.77.

2.2 Mortars

The rendering mortar mass proportions 1:1:6 (cement:lime:sand) typically used in Pelotas, which corresponds to more approximate proportions values found in mortars reconstitution of the buildings in the historic center of Pelotas, was chosen as the reference mortar. In the other mixtures, here studied, the type of addition was varied to compose the following binders: cement + hydrated lime (CHA), cement + artificial hydraulic lime (CHB) and cement + quicklime paste (CV). Table 1 summarizes the quantities of materials used for the different mortars proportions. The amount of water obtained in the reference mortar (1:1:6) using the flow table test (consistency test) was fixed as the quantity necessary to attain an average spread diameter of 167 mm (67% above the cone base diameter). To achieve this consistency value, 200 mL of water was used, which corresponds to 13% of the volume of material used in the reference mortar. This water quantity was fixed and applied to others mortars (1:0.33:3.7-1:1:7-1:4:14), regardless of the different additions types.

2.3 Methods

The voids index of hardened rendering mortars was determined on three cylindrical specimens (50 mm in diameter and 100 mm in height) for each type of mortar taking into account the water absorption method according to NBR 9778/1987 [3].

The capillary water absorption test was performed on prismatic specimens with dimensions of 40 mm × 40 mm × 160 mm. The specimens used in the test were first conditioning during 28 days in a curing chamber and after the specimens were submitted a drying-wetting procedure till the age of 240 days. These conditions were considered close to those that mortar will present when the buildings are subjected to climatic effects. The applied test method is described in the report 140/00—NCCT LNEC [4]. Fig. 1 illustrates a sequence of the test procedure involving the determination of the dry mass, the water contact of test specimens and periodic weighing after contact.

The compressive strengths at 7 and 28 days were determined on 6 cylindrical samples (50 mm diameter and 100 mm height) according to NBR 7215 [5]. The tensile strength in bending on prismatic specimens was determined at 28 days, according to the NBR 12142 [6].

The measurement of water absorption under low pressure (water permeability) test was applied on masonry panels coated with the mortars studied, as shown in Fig. 2, according to the “pipe method” described by Polisseni [8].

Table 1 Compositions and proportions of mortars.

Mortar mass proportions	Cement (g)	Lime (g)	Sand (g)	Water (g)	Water/cement ratio	Water/binder ratio
1:1:6	193	193	1154	200	1.04	0.52
1:0.33:3.7	306	106	1128	200	0.65	0.49
1:1:7	171	171	1197	200	1.17	0.58
1:4:14	81	324	1135	200	2.40	0.48

Fig. 1 Water capillarity absorption test procedure.

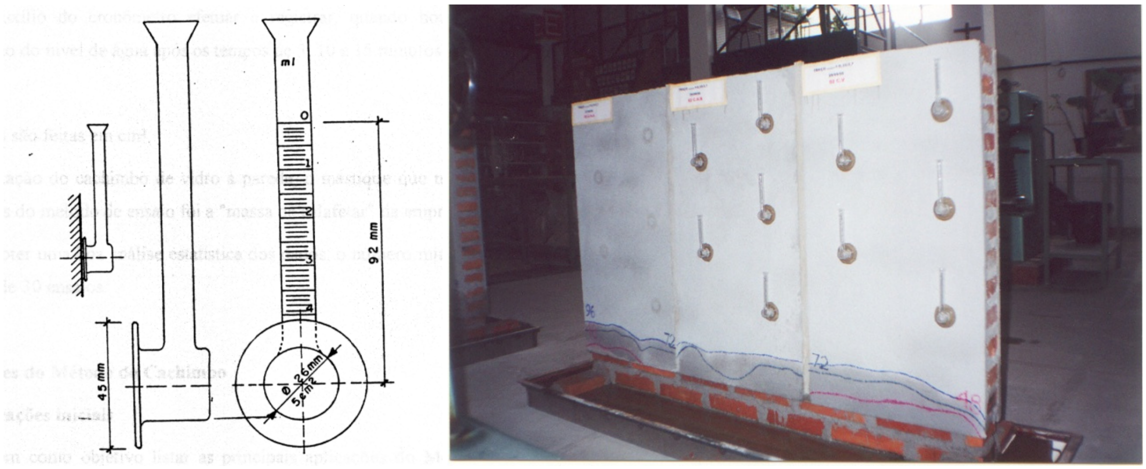

Fig. 2 Water permeability testing on panels coated with mortar.

In this method, the measurement of mortar water absorption is carried out under an initial pressure due to a water column height of 92 mm, which corresponds to static action with wind speed about 0.28 m/s, where the height of the column corresponds to the water pressure (kgf/m^2) exerted by this column (1 mm water column corresponds to 1 $kgf/m^2 \cong 10$ Pa).

The determination of soluble salts content in rendering mortar samples extracted from the masonry panels produced in the laboratory was performed according to NBR 9917/1987 [9]. After the panels have been subjected to the action of water containing 5% sodium sulphate for a period of 24 months, the mortar specimens were extracted from masonry panels with a cup-saw tool. The mortars specimens showing no visually efflorescence and/or crypto-efflorescence were subjected to a test to determine the internal salts content.

3. Results and Discussion

The results obtained were analyzed using the ANOVA statistical test. The variables as mortar binder type and mortar proportions, presented in Table 2, were compared with each other at different levels. The statistical test used chooses a comparison variable for the purpose of solving the probability of no significant difference between them. In the case of binder type, the cement + quicklime rendering mortar (CV) was fixed as reference and in the case of mortar proportion it was the mortar proportion 1:4:14.

The results of the effects analysis on voids ratio presented in Table 3 confirms with probability $p < 0.05$ that among them, only a level of mortar proportion variable 1:1:7 was not significantly distinguishable from the effects of the others evaluated variables. The numbers identified as "parameter" in the third column

Table 2 Mortars variables.

Column	Mortar variable	Variable level	Versus level
1	Binder type	CHA	CV
2	Binder type	CHB	CV
3	Proportion	1:1:6	1:4:14
4	Proportion	1:0.33:3.7	1:4:14
5	Proportion	1:1:7	1:4:14

Table 3 Results of variables effects analysis on mortars voids ratio.

Level effect	Column	Parameter	Std.Err	*t*	*p*
CHA	1	-0.2658	0.1202	-2.210	0.034
CHB	2	-0.5358	0.1202	-4.456	0.000
1:1:6	3	-0.6736	0.1472	-4.574	0.000
1:0.33:3.7	4	-0.7102	0.1472	-4.823	0.000
1:1:7	5	-0.2213	0.1472	-1.503	0.143

p = probability of variable significance, $p < 0.05$.

Table 4 Results of variables effects analysis on mortars coefficient of capillarity.

Level effect	Column	Parameter.	Std.Err	t	p
CHA	1	0.0259	0.0244	1.059	0.297
CHB	2	-0.0450	0.0244	-1.839	0.075
1:1:6	3	-0,0378	0.0299	-1.262	0.216
1:0.33:3.7	4	-0.1055	0.0299	-3.522	0.001
1:1:7	5	-0.0402	0.0299	-1.341	0.189

Table 5 Results of variables effects analysis on mortars compressive and flexure strengths at 28 days.

Level effect	Column	Compressive strength				Flexure strength			
		Parameter	Std.Err	*t*	*p*	Parameter	Std.Err	*t*	*p*
CHA	1	0.2594	0.3700	0.701	0.488	0.1902	0.0510	3.725	0.000
CHB	3	-0.4147	0.3700	-1.120	0.271	-0.0530	0.0510	-1.038	0.307
1:1:6	3	0.0961	0.4532	0.212	0.833	0.0408	0.0625	0.652	0.518
1:0.33:3.7	4	2.4594	0.4532	5.426	0.000	0.2019	0.0625	3.228	0.003
1:1:7	5	-0.7816	0.4532	-1.724	0.094	-0.0169	0.0625	-0.270	0.788

of Table 3 indicate the level of influence on the voids ratios. The negative sign refers to the reduction effect of voids ratio which represents here a mortar characteristic porosity. The use of artificial hydraulic lime CHB has a reduction effect superior than the hydrated lime. In fact, this reductive effect could be caused by rice husks ash, which is part of this industrial product, where their fineness and their reactivity have a leading role. The increase of fine aggregate in mortars is directly related to lower compactness and therefore higher voids ratio.

The results of the effects analysis on mortar capillarity coefficient that is defined by the slope of the line formed between the amount of water absorption at 10 min and 90 min, shown in Table 4, allow to identify significant differences in mortar proportions 1:0.33:3.7. The parameter related to these proportions indicates that both the decreased of addition as fine aggregate amounts contribute to the significant reduction in the mortar capillary coefficient. On the other hand, the significant influence of this mortar proportion means that a reduction, around 71%, of mortar capillarity coefficient was attained increasing the binders content.

Regarding the mechanical strengths at 28 days, the parameters of Table 5 shows the mortar compressive and flexure strengths increasing with the addition reduction; as well as hydrated lime also increases significantly the mortar flexure strength. Thus, it is possible to conclude that hydrated lime in the mortar proportion 1:0.33:3.7 provided the highest significant mechanical strengths. But, it is also clear that the increase of the mechanical strength comes from the decrease in the addition content that means a large presence of cement in the mortar.

The results of variables effects analysis on mortar water permeability are shown in Table 6. It is possible to identify that hydrated lime addition was the only significant variable. It means that a reduction of water permeability around 27% could be attained when the hydrated lime is incorporated in the rendering mortars.

The results of the soluble salt content (sodium sulphate) analysis recorded in Table 7 show that the permanence of the masonry panels in contact with water containing salt led to a widespread presence of sulphate in all studied mortars, even those who had little or no manifestation of efflorescence, indicating that in these cases, the crystallization of the salt was formed in the substrate zone and/or within the mortar.

In the specific case of reference mortar proportion 1:1:6, mortar proportion 1:0.33:3.7 and 1:1:14, which visually demonstrated high rate of efflorescence and crypto-efflorescence, high levels of sulphates in most of samples were also observed. This observation indicates that in these mortars, the water and salts reaches the outer surface of the wall, giving rise to crystallization. In mortar proportion 1:1:7, especially the mixtures composed by hydrated lime (CHA) and by quicklime paste (CV), was visually observed a small sign of efflorescence and crypto-efflorescence. The CV rendering mortar showed the highest salt content of all mortars studied. In the specific case of CHB rendering mortar (1:1:7), although not outwardly demonstrating the crystalline salts formation, the salts were formed inside the mortar. In this case, it meets the objectives sought, that is, water contaminated by soluble salts disappears as vapor, leaving inside the pores the recrystallized soluble salts formations, not leading to the coating outer surface. Thus, for a long period of time, the efflorescence and/or crypto-efflorescence anomalies will not be observed.

Table 6 Results of variables effects analysis on mortar water permeability.

Level effect	Column	Parameter	Std.Err	*t*	*p*
CHA	1	-0.2797	0.1073	-2.604	0.014
CHB	2	0.1352	0.1073	1.259	0.217
1:1:6	3	-0.1972	0.1315	-1.499	0.144
1:0.33:3.7	4	-0.0272	0.1315	-0.206	0.8374
1:1:7	5	-0.0205	0.1315	-0.156	0.8768

Table 7 Soluble salts concentrations in mortars.

Mortar proportions	Additions	% SO_4
1:1:6	CHA	1.26
	CHB	1.55
	CV	1.03
1:0.33:3.7	CHA	2.28
	CHB	1.13
	CV	0.11
1:1:7	CHA	0.68
	CHB	0.61
	CV	2.23
1:1:14	CHA	0.88
	CHB	1.56
	CV	4.87

4. Conclusions

The main conclusions of the analysis of variance carried out on the tests results performed in this study are, in summary, the following:

In general, the change in fine aggregates quantities directly influences the mechanical strength of mortars, increasing the load capacity to compressive and tensile stresses inversely to the fine aggregates content. These variations are inverted due mainly to the fact that increasing the aggregate content leads to higher voids content with lower availability of binders (cement and addition) to fill the gaps, creating low compactness and internal cohesion. Thus, the rendering mortar mechanical strengths were reduced.

Whatever the type of addition, the capillary coefficients of rendering mortars were similar. The fine aggregate increasing leads to higher values of this coefficient, indicating that the higher porosity, existing due to the high void content, ends up determining a higher initial water absorption contacting the surface of the specimens.

The results of permeability tests by the pipe method indicated no influence of the fine aggregates amount but a significant influence of addition type. In this case, the hydrated lime addition had a significant contribution on the water permeability reduction.

From the analysis of variance, it was possible to observe that the rendering mortars with higher fine aggregates content present salts crystallization on surfaces much later on, indicating that largest voids longer retain the salts soluble therein, hindering and delaying the efflorescence formations.

Finally, taking into account the experimental results mainly concerning the water absorption properties measured in this study, it is attested the best performance of the CHA in the mortar proportion 1:0.33:3.7.

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Soil Characteristics in Selected Landfill Sites in the Babylon Governorate, Iraq

Ali Chabuk[1], Nadhir Al-Ansari[1], Hussein Musa Hussein[2], Suhair Kamaleddin[3], Sven Knutsson[1], Roland Pusch[1] and Jan Laue[1]

1. Department of Civil Environmental and Natural Resources Engineering, Lulea University of Technology, Lulea 971 87, Sweden;

2. Department of Geology, Faculty of Science, University of Kufa, Kufa 31003, Iraq;

3. Iraqi Ministry of Housing & Construction, National Center for Construction Laboratories and Research Babylon, Baghdad 1001, Iraq

Abstract: The Babylon Governorate is situated in the middle of Iraq. It covers an area of 5,315 km^2 and has 2,092,998 inhabitants distributed throughout its five major cities (Qadhaa). Presently, there is no landfill site in the governorate that meets the environmental criteria for the disposal of municipal and industrial waste. Consequently, GIS (geographic information system) and methods of multi-criteria decision making were used here to select the best sites in each city in the Babylon Governorate that would fulfil the environmental requirements. Two sites were chosen in each city. As the groundwater is very shallow in this area, the design should ensure against groundwater pollution by leachate from these sites. To avoid this problem, soil investigation was conducted at these sites so that the most suitable landfill design could be accomplished. The results of soil investigation in these sites include the soil profile, groundwater depth, chemical properties, allowable bearing capacity, Atterberg limits test results and material characteristics of the soil strata. From the research, it is believed that the best design is one that puts the landfill above ground.

Key words: Bearing capacity, Atterberg limit, landfill, Babylon, Iraq.

1. Introduction

The location of landfills and the methods of disposing of solid waste at a site can create serious environmental problems. The greatest concerns regarding landfill's impact on the environment are related to its effects on ground water, surface water, air, soil, as well as the odor produced and issues arising from the transportation of solid waste [1]. Landfills are still considered the most popular method of disposal for solid waste. The increasing rate of population growth, improving standards of living, industrial growth and increasing commercial activities are major factors behind the increase in the quantity of waste produced around the world [2-4]. About 95% of solid waste that is generated in the world is disposed of in landfills [3, 4]. In the past, landfill sites were not well managed, especially where there were limited restrictions upon the type of waste dumped in landfills. Different kinds of industrial, household and sometimes toxic wastes were mixed together in the same landfill [3, 5].

The site selection process for landfill is considered to be one of the most complex tasks related to solid waste management systems because many factors must be taken into consideration. Examples of such factors include government and municipal funding, government regulation, social and environmental factors, concerns for public health, growing environmental awareness, reduced land availability for landfills and increasing political and social opposition to the establishment of landfill sites [6-9]. In the 1930s, the United States was one of the countries that saw the earliest changes in the development of sanitary landfills through depositing the solid waste in layers, compacting it, and then covering it with soil on a daily basis. Many countries (such as Canada, the United

Corresponding author: Nadhir Al-Ansari, professor; research fields: water resources and environment. E-mail: nadhir.alansari@ltu.se.

States, Australia and Sweden) implemented stringent governmental regulations relating to the selection, design and monitoring of modern landfills in order to avoid negative social and environmental impacts [3].

GIS s (geographic information system) and MCDM (multi-criteria decision making) methods are recommended for siting landfills because they are powerful and integrated tools that are able to solve the problems that arise in landfill site selection. Decision makers often use MCDA (multi-criteria decision making analysis) to handle large quantities of complex information. In MCDM methods in this context, weightings for criteria maps are derived and used alongside GIS to identify a suitable landfill site. Many methods of multi-criteria decision making analysis can be used. GIS is one of these approaches, and it has a high ability to manage large volumes of spatial data and simulate the required effect factors from a variety of sources [10-12].

Babylon Governorate is situated in the Mesopotamia Basin, which is referred to historically as the area located between the Tigris and Euphrates Rivers. It is essentially a flat terrain, with a gentle slope from northwest to the southeast towards the Arabian Gulf. The Mesopotamia Basin is mainly covered by different types of Quaternary sediments. The Quaternary Period comprises different sediment types. Depending on their genesis, the sediments are classified as fluvial, lacustrine, aeolian, polygenic anthropogenic sediments, and gypcrete [13]. The area in this governorate is also characterized by its shallow groundwater. The water table varies in depth from 0.423 m to 15.97 m below the surface of the ground in most of the areas.

There are 11 types of soil distributed within the Babylon Governorate [14]. These types are: (1) gypsiferous gravel soils; (2) mixed gypsiferous desert land; (3) sand dune land; (4) active dune land; (5) river levee soils; (6) silted haur and marsh soils; (7) river basin soils, poorly drained phase; (8) river basin soils, poorly drained phase; (9) basin depression soils; (10) haur soils; and (11) periodically flooded soils. These soil types were used as categories to select landfill sites in each city in the Babylon Governorate, with each type given an appropriate weighting based on its importance in preventing groundwater contamination by leachate from waste.

In selecting a landfill site, the main purpose of conducting soil investigation is usually to acquire the necessary data to study the different strata of soil at the selected sites and to know the groundwater depth at the sites [15]. The soil investigations at each site include knowing the characteristics of the subsoil profile for distributed samples marked (D), undisturbed samples marked (U) and split spoon samples marked (S.S.). In addition, the Atterberg limits of fine grained soils, the thickness of each stratum, and the allowable bearing capacity of the soil are required in order to estimate both the quantities of solid waste that can be put at each site, and the groundwater depth for each site. The chemical properties for the soil are also measured. This involves assessing the percentage of sulphate, chloride, and gypsum, the TSS (total soluble salts) and the organic material content for the soil samples plus the sulphate content (mg/L) for the water samples.

Refs. [16-22] assess potential landfill sites using GIS and MCDA methods in the field. The main aim of this study was to conduct soil investigations on the selected landfill sites in the Babylon Governorate in order to determine the best landfill design for these sites.

2. Study Area

Babylon Governorate is located in the middle of Iraq, about 100 km to the south of the Iraqi capital, Baghdad [23]. It is situated between latitude 32°5'41" N and 33°7'36" N, and longitude 44°2'43" E and 45°12'11" E (Fig. 1). The Babylon Governorate includes one of the most famous cities of the ancient world, Babylon, which was considered the power centre of an influential empire. The Babylon Governorate covers an area of 5,315 km^2 [24]. It has a population of 2,092,998 inhabitants (2015 census figures), distributed throughout its main cities [25]. Administratively, the

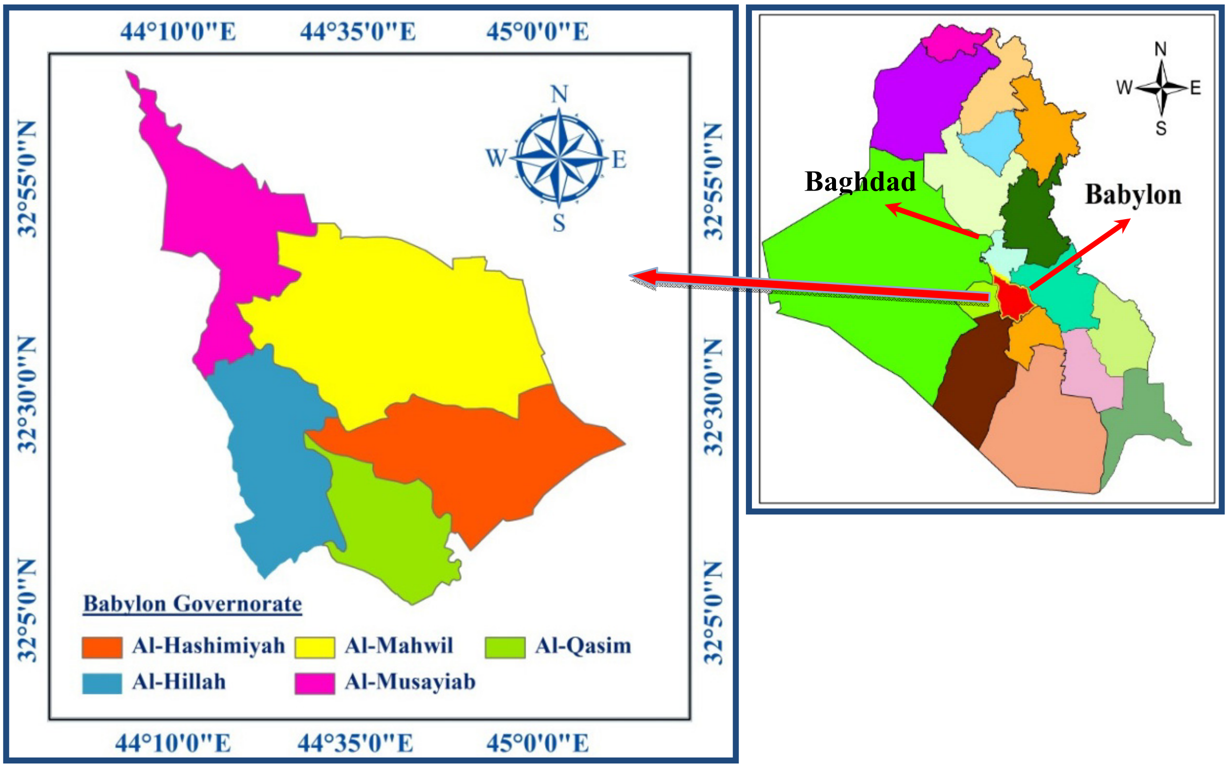

Fig. 1 The Babylon Governorate, Iraq.

Babylon Governorate consists of five major cities, referred to as Qadhaa. These Qadhaa are Al-Hillah, Al-Hashimiyah, Al-Musayiab, Al-Mahawil and Al-Qasim. Sixteen smaller cities are geographically and administratively connected to these major cities, and these are called Nahiah.

The governorate is characterized by comparatively flat and inclining land. The northern part of the Babylon Governorate rises to about 60 m above mean sea level, and the southern part falls to about 20 m above mean sea level. The lands of the Babylon Governorate are fertile, and the Shatt Al-Hillah River passes through most cities in the governorate. This river branches off from the Euphrates River at the city of Sadah in the north of the governorate in Al-Musayiab Qadhaa [24, 26].

3. Selected Candidate Landfill Sites

In order to select candidate sites for landfill in the five Qadhaas in the Babylon Governorate that would meet the environmental and scientific criteria, GIS software and multi-criteria decision making methods were used. Fifteen of the most important criteria were selected and incorporated into GIS for the analysis process with the intention of producing a map with which to select the best sites for landfill in each Qadhaa in the governorate. These criteria are groundwater depth, urban centers, rivers, villages, soil types, elevation, agriculture, roads, land slope, land use, archaeological sites, power lines, gas pipelines, oil pipelines and railways.

The required maps for this study were prepared using multiple sources. The first source was already available digital maps (shape files), and the second source was drawn from published maps, with the relevant information from each map converted to a digital map format. The third source was already available data, which were entered in a GIS to produce a digital map after generating the interpolation between these data. For the current study, the literature review, the opinions of experts in this field, various requirements, regulations and available data about the study area were all used to classify each criterion into categories (sub-criteria). Subsequently, each category was assigned a suitability score. To prepare each criterion and sub-criteria for analysis, many steps were performed in a GIS environment using special analysis tools.

Each candidate site was selected from within the category of the most suitable area in the final map for landfill siting (Fig. 2) based on the estimated quantity of cumulative solid waste which will be generated from 2020 to 2030, as calculated by Chabuk et al. [26]. Based on this condition, the final map of selected sites for landfill in the Babylon Governorate shows the location and the area required for each site (Table 1).

4. Soil Investigations

The selected candidate sites for landfill in Babylon Governorate were checked against the satellite images (2011) of the Babylon Governorate [27] to make sure that these sites were suitable for landfill in the Qadhaas of the Babylon Governorate.

To check the soil characteristics in the selected sites for landfill in the field, soil investigations were conducted for the prime candidate sites in 2016 by the Iraqi Ministry of Housing & Construction—National Center for Construction Laboratories and Research Babylon, Iraq (Fig. 3) [28]. Details of the soil investigations in these selected sites are as follows.

4.1 Field Exploration in the Selected Sites

4.1.1 Drilling and Sampling

Drilling was done using flight augers. The diameter of the drilled bore holes was 15.0 cm. The distributed samples (D) were collected from the auger cuttings at different depths. The undisturbed samples, marked (U), were obtained using Shelby tubes. Split spoon samples (S.S.) were obtained from a standard split spoon used in the S.P.T (Standard Penetration Test) which was performed for every test boring at different intervals depending on the stratification of the soil.

4.1.2 Number of Bore Holes and Their Depth

Two borehole locations were assigned for each site by the local authority concerned, and the boreholes were drilled to a specific depth below ground surface (N.G.S).

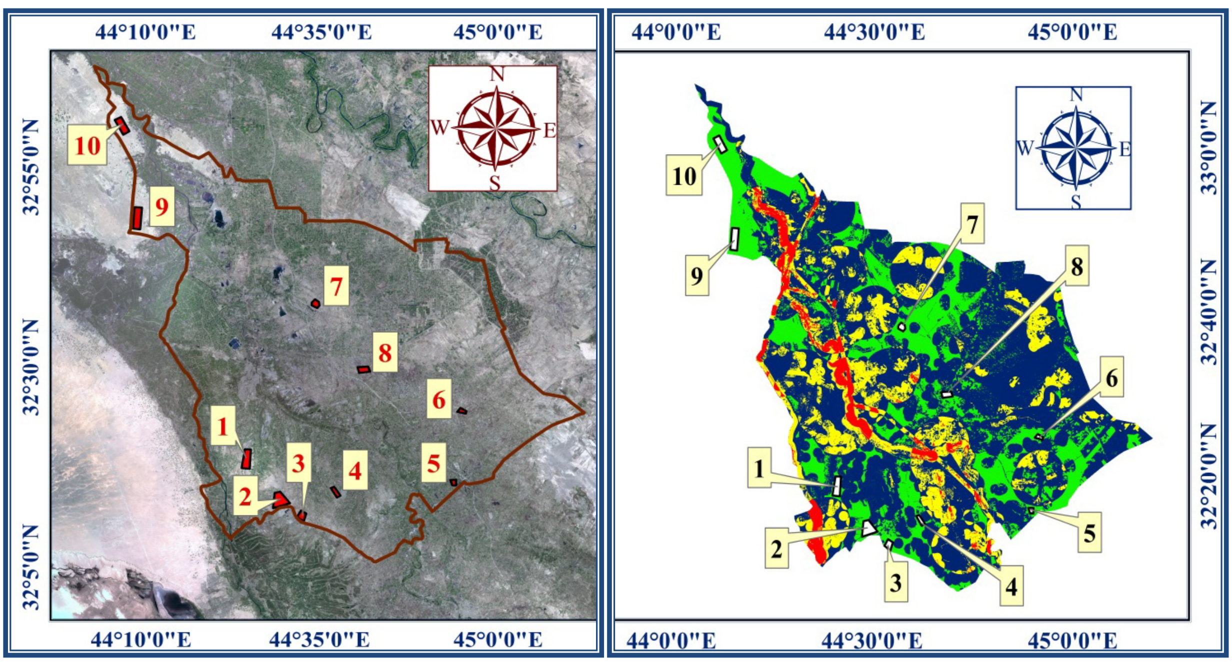

Fig. 2 Candidate sites for landfill in the Babylon Governorate.

Table 1 Landfill in the Qadhaas of the Babylon Governorate.

Qadhaa (city)	Required area (km^2)	Area of candidate sites		Location	No. of site in Fig. 2
		Site	Area (km^2)		
Al-Hillah	Method 1 4.175	No. 1	6.768	Latitude 32°18'45" N Longitude 44°24'40" E	1
	Method 2 4.778	No. 2	8.204	Latitude 32°13'43" N Longitude 44°29'15" E	2
Al-Qasim	Method 1 0.577	No. 1	2.766	Latitude 32°11'43" N Longitude 44°32'26" E	3
	Method 2 0.772	No. 2	2.055	Latitude 32°14'38" N Longitude 44°37'10" E	4
Al-Hashimiyah	Method 1 0.844	No. 1	1.374	Latitude 32°24'51" N Longitude 44°54'41" E	6
	Method 2 1.013	No. 2	1.288	Latitude 32°15'54" N Longitude 44°53'38" E	5
Al-Mahawil	Method 1 0.738	No. 1	2.218	Latitude 32°38'12" N Longitude 44°34'9" E	7
	Method 2 0.975	No. 2	2.950	Latitude 32°29'59" N Longitude 44°41'2" E	8
Al-Musayiab	Method 1 1.674	No. 1	7.965	Latitude 32°48'39" N Longitude 44°8'59" E	9
	Method 2 2.080	No. 2	5.952	Latitude 33°0'14" N Longitude 44°6'46" E	10

Fig. 3 Soil investigations works at candidate sites in the Babylon Governorate.

5. Results

5.1 Subsoil Stratification

The subsoil profile for the selected sites in each Qadhaa in the Babylon Governorate was analyzed according to the USCS (Unified Soil Classification System) (ASTM 2487), which is generally used in assessing the engineering properties of soils and is based on grain size and plasticity characteristics (Atterberg limits).

5.1.1 Soil Profile for Al-Hillah City, Al-Hillah Qadhaa

The subsoil profile for Al-Hillah City, Al-Hillah Qadhaa (borehole site No. 1) can be summarized as follows:

The first layer is fill material to a thickness of about 0.5 m.

The second layer is about 2.0 m thick, consisting of red brown, medium to very stiff, silty clay with gypsum and organic material, and containing a thin layer of brown, medium clayey, sandy silt and organic material of about 0.5 m in thickness.

Then, there is a layer of brown, red, stiff to very stiff, silty clay with gypsum and organic material of about 6.0 m in thickness, and containing a thin layer of brown, medium clayey, sandy silt and organic material that is about 0.5 m thick.

The last layer is yellow, grey, medium silty sand to the end of the bore.

The underground water level was encountered at a depth of 2 m below the ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the overall soil stratification are shown in the borehole log and soil profile (Fig. 4).

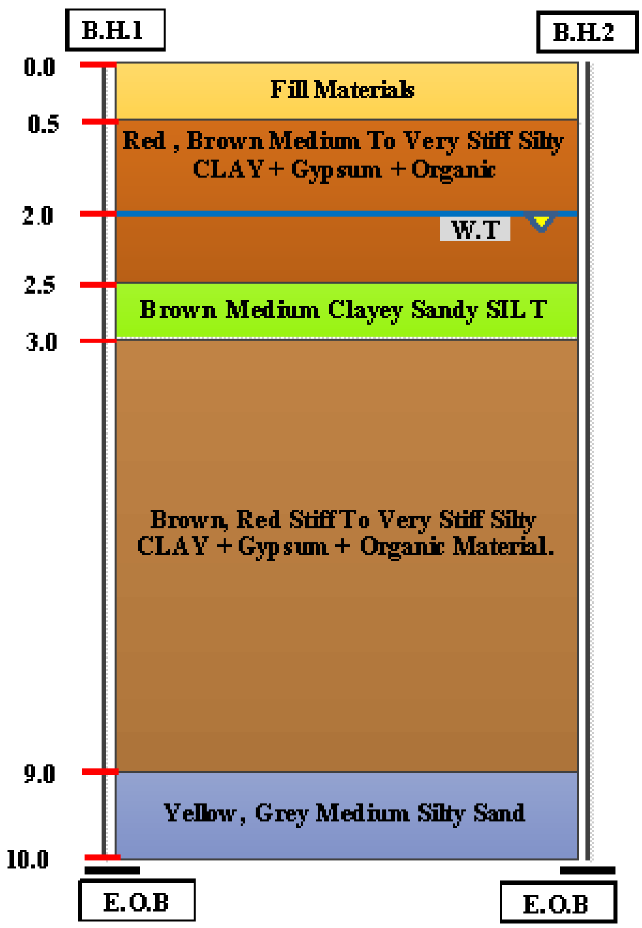

Fig. 4 Soil profile for Al-Hillah City, Al-Hillah Qadhaa.

5.1.2 Soil Profile for Al-Kifil City, Al-Hillah Qadhaa

The subsoil profile for Al-Kifil City, Al-Hillah Qadhaa (site No. 2) can be summarized as follows:

The first layer is about 7.5 m thick, consisting of brown, stiff to hard, sandy silty clay (CL, MH-OH) with organic material. It also contains a thin layer of brown, clayey, silty sand of about 0.5 m in thickness.

Then, there is a layer of brown, medium to very dense, clayey, silty sand (river sand) which extends down to the end of the bore below N.G.S.

The underground water level was encountered at a depth of 2 m below the ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification are shown in the borehole log and soil profile (Fig. 5).

In Al-Qasim City, Al-Qasim Qadhaa (site No. 2), the subsoil profile can be summarized according to the unified classification system as follows:

The upper layer is fill material of about (0.5-1.0) m in thickness.

Then, there is a layer of brown, stiff, silty clay of about (0.5) m in thickness.

The following layer is brown, medium clayey silty sand.

The main layer is brown, grey medium to very stiff, sandy silty clay and silty clay (CH-CL) with organic material, iron oxide, roots, shells and gypsum which extends down to the end of the bore. This layer also contains a thin layer of brown black, medium clayey, silty sand (river sand).

5.1.3 Soil Profile for Al-Qasim city, Al-Qasim Qadhaa

The underground water level was encountered at a depth of 2.2 m below the ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 6).

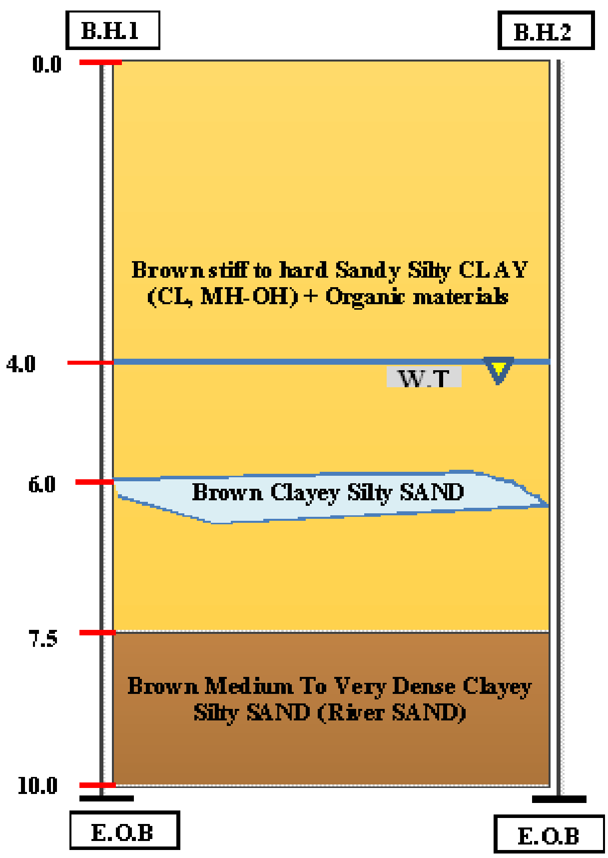

Fig. 5 Soil profile for Al-Kifil City, Al-Hillah Qadhaa.

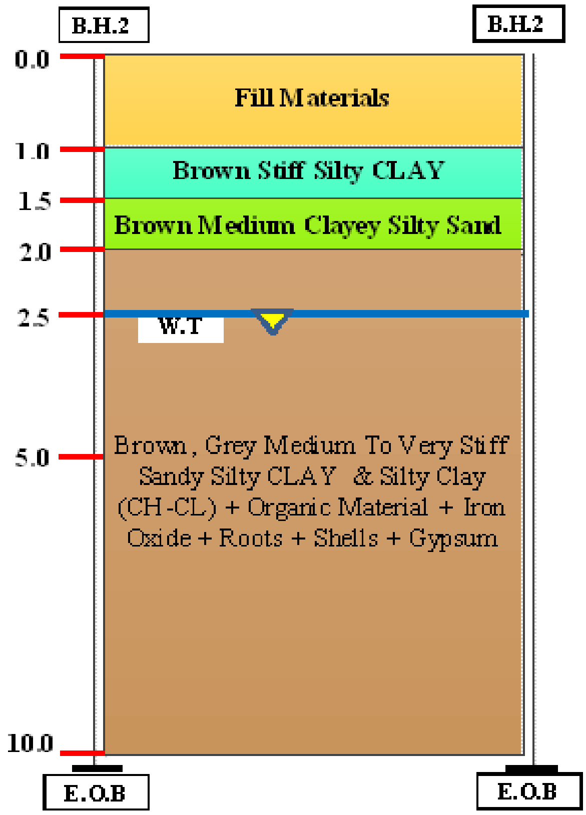

Fig. 6 Soil profile for Al-Qasim City, Al-Qasim Qadhaa.

5.1.4 Soil Profile for Al-Talyaah City, Al-Qasim Qadhaa

The subsoil profile for Al-Talyaah City, Al-Qasim Qadhaa (borehole site No. 1) is similar to the subsoil profile from Al- Kifil City, Al-Hillah Qadhaa (borehole site No. 2). These sites are located in the same area and have similar properties, and the distance between these sites is about 4 km.

Here, however, the underground water level was encountered at a depth of 4.7 m below ground surface (G.S.), measured 24 hours after drilling terminated.

5.1.5 Soil Profile for Al-Medhatyah City, Al-Hashimiyah Qadhaa

The classification and description for the subsoil profile for Al-Medhatyah City-Al-Hashimiyah Qadhaa (borehole site No.1) according to the unified classification system can be summarized as follows:

The first layer is fill material of about 1.2 m in thickness.

Then, there is a brown, soft sandy silty clay (CL) with roots to a thickness of about 0.5 m.

The following layer is brown, loose to medium sandy clayey silt with roots, and extending down to a depth of about 8 m below the ground water surface. This layer includes a lense of brown, medium sandy, silty clay (CL).

Next is a layer of brown, medium to stiff, sandy silty clay (CL-CH) that extends down to 10 m below the ground surface.

The underground water level was encountered at a depth of 3.8 m below the ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 7).

5.1.6 Soil Profile for Al-Shomaly City, Al-Hashimiyah Qadhaa

According to the unified classification system, the subsoil profile for Al-Shomaly City, Al-Hashimiyah Qadhaa (borehole site No. 2) can be summarized as follows:

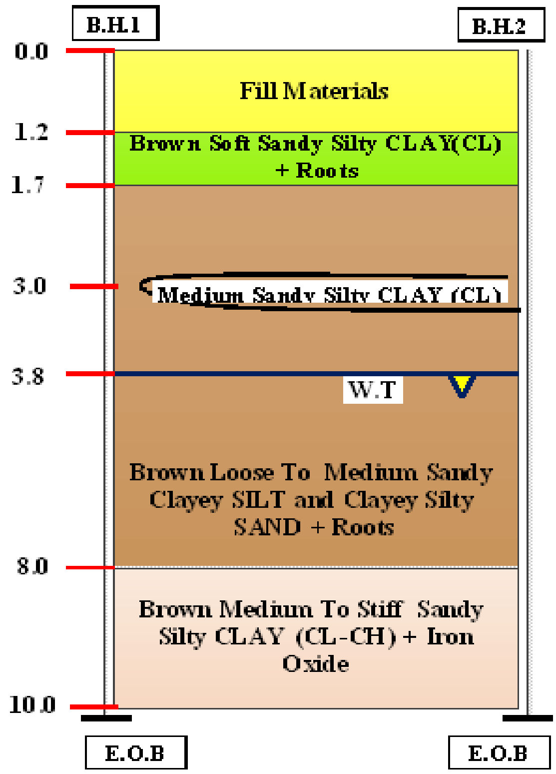

Fig. 7 Soil profile for Al-Medhatyah City, Al-Hashimiyah Qadhaa.

The first layer is fill material of about 0.7 m in thickness.

The next layer is brown and grey, soft to very stiff, silty clay with organic material and iron oxide of about 6 m in thickness. This layer also contains a lense of brown, medium clayey silt of about 0.75 m in thickness.

Then, there is a layer of brown, medium sandy, clayey silt of about 1 m in thickness.

The following layer is brown and black, medium silty clayey sand (river sand) down to a depth of 9 m below N.G.S.

The last layer is brown, very stiff to hard clay down to the end of the bore.

The underground water level was encountered at a depth of 4 m below ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 8).

5.1.7 Soil Profile for Al-Imam City, Al-Mahawil Qadhaa

The subsoil profile for Al-Imam City, Al-Mahawil Qadhaa (borehole site No. 1) can be summarized according to the unified classification system as follows:

The first layer is fill material of about 0.5 m in thickness.

The main layer is brown, black medium to very stiff, silty clay with gypsum and organic material down to about 9.5 m below G.S.

The last layer is brown, medium sandy, clayey silt with iron oxide and is about 0.5 m thick.

The underground water level was encountered at a depth of 2.7 m below ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 9).

5.1.8 Soil Profile for Al-Neel City, Al-Mahawil Qadhaa

The Al-Neel city, Al-Mahawil Qadhaa (borehole site No. 2) subsoil profile can be summarized according to the unified classification system as follows:

The main layer is brown, medium to very stiff, silty

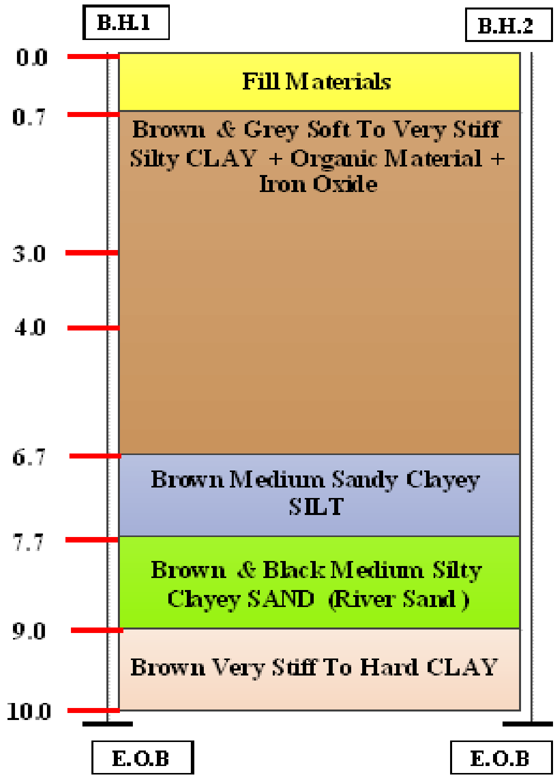

Fig. 8 Soil profile for Al-Shomaly City, Al-Hashimiyah Qadhaa.

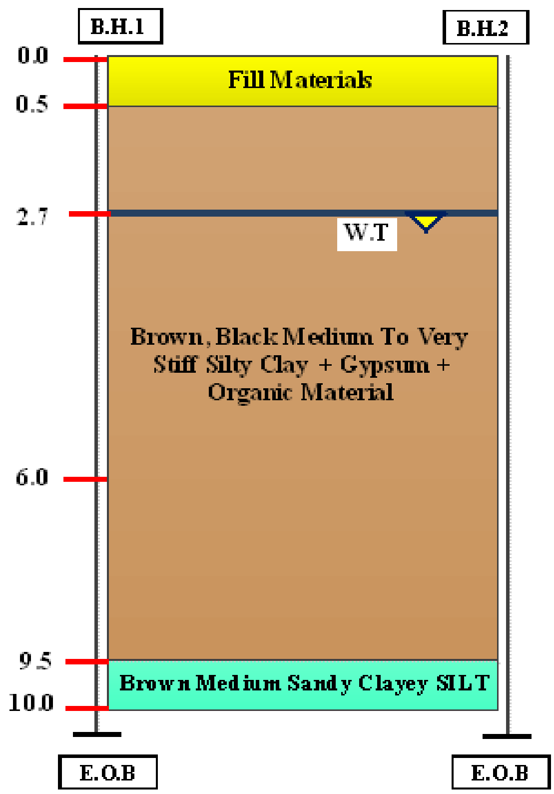

Fig. 9 Soil profile for Al-Imam City, Al-Mahawil Qadhaa.

clay and sandy silty clay (CH- CL- OL) with organic material and iron oxide.

The underground water level was encountered at a depth of 2.1 m below ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 10).

5.1.9 Soil Profile for JurfAl-Sakhar City, Al-Musayiab Qadhaa

Due to the security situation in this area, where people are not allowed to visit this area, the work was based on previous data available at governmental departments. According to the unified classification system, the subsoil profile for Jurf Al-Sakhar City-Al-Musayiab Qadhaa can be summarized as follows:

The upper layer is brown, medium dense, highly gypsums, silty sand extending down to 2 m below N.G.S.

Then, there is a layer of brown, stiff, highly gypsum, sandy silty clay extending down to about 9 m below N.G.S.

Finally, there is a layer of dense to very dense, silty sand extending down to the end of the bore.

The underground water level was encountered at a depth of 10 m below ground surface (G.S.), measured 24 hours after drilling terminated.

Details of the soil stratification for the hole are shown in the borehole log and soil profile (Fig. 11).

5.2 Chemical Properties

The results of the chemical tests for the soil and water samples are shown in Table 2. These results show the percentage of sulphate, chloride, and gypsum content, the TSS content and the organic material content for the soil samples. For the water samples, only the sulphate content (mg/L) was measured.

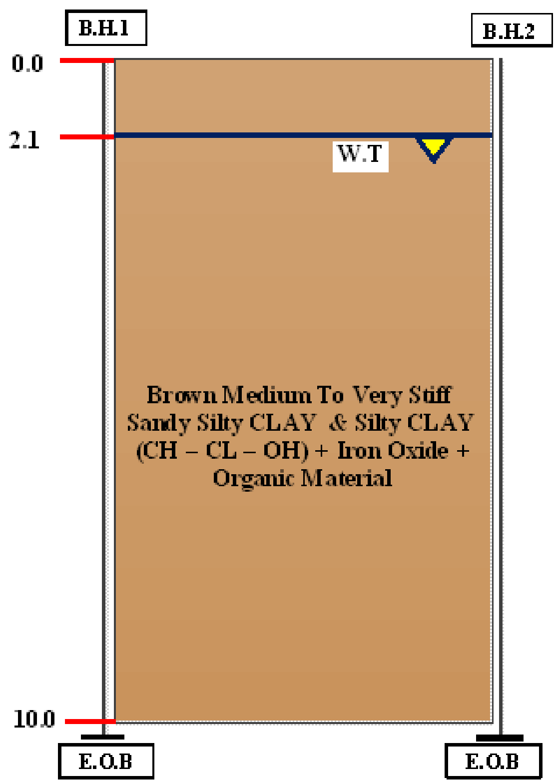

Fig. 10 Soil profile for Al-Neel City, Al-Mahawil Qadhaa.

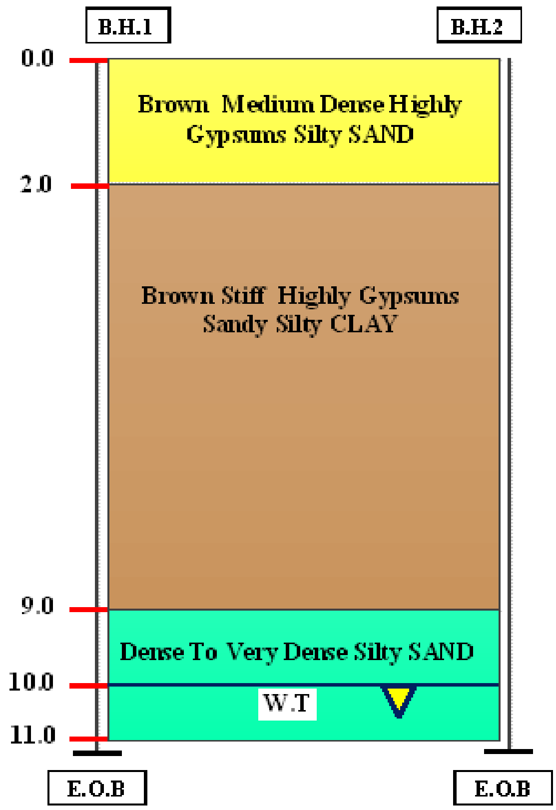

Fig. 11 Soil profile for JurfAl-Sakhar City, Al-Musayiab Qadhaa.

Table 2 Results of the chemical tests for soil and water samples.

Qadhaa	City	Borehole site No.	Sulphate content (%)	Chloride content (%)	Gypsum content (%)	TSS (%)	Organic material content (%)	Sulphate content in water (mg/L)
Al-Hillah	Hillah	1	0.21-3.13	0.018-0.213	0.45-6.73	0.94-8.92	1.06	276.1
Al-Hillah	Kifil	2	0.05-0.59	0.01775-0.01778	0.11-0.59	0.23-0.82	0.54-1.89	389.6
Al-Qasim	Talyaah	1	0.05-0.59	0.01775-0.01778	0.11-0.59	0.23-0.82	0.54-1.89	389.6
Al-Qasim	Qasim	2	0.32-4.75	0.018-0.378	0.69-10.22	1.21-11.81	0.11-0.95	384.5
Al-Hashimiyah	Medhatyah	1	0.04-0.14	0.018-0.036	0.162-0.29	0.52-0.97	-	61.9
Al-Hashimiyah	Shomaly	2	0.121-0.66	0.124-0.568	0.26-1.42	0.58-1.77	1.40	290.5
Al-Mahawil	Imam	1	0.195-2.978	0.0177-0.0178	0.42-6.4	0.79-9.21	0.39	266.1
Al-Mahawil	Neel	2	0.161-0.823	0.0177-0.0355	0.35-1.77	1.2-2.5	0.84-1.76	97.21
Al-Musayiab	JurfAl-Sakhar	1+2	0.62-22.5	0.07-0.11	1.33-48.46	2.4-51.4	4.0-4.71	178.4

5.3 Allowable Bearing Capacity

The allowable bearing capacity at different depths in meters below the G.S. profile in each Qadhaa in the Babylon Governorate differs from one site to another based on the soil profile for each selected site, as shown in Table 3.

5.4 Atterberg Limits Test Results

Generally, the values of the liquid limit (L.L), plasticity index (P.I) and moisture content (M.C) at different depths indicate the natural moisture content of each soil profile based on the test results in each site. These are shown in Table 4.

5.5 Soil Classification and Material Characteristics

The soil texture types are classified according to two general methods of soil classification: the USDA (US Department of Agriculture) texture classification system and the USCS (Unified Soil Classification System) (ASTM 2487). The USDA system, used by soil scientists and agronomists, is based principally on texture (grain size distribution). The USCS system is generally used in assessing the engineering properties of soils and is based on grain size and plasticity characteristics (Atterberg limits). The characteristics of materials in each stratum of soil were estimated in the laboratory (Table 5).

Table 3 Allowable bearing capacity at different depths below G.S. for each site.

Qadhaa	City	Site No.	Depth (m) Below G.S.	Allowable bearing capacity (t/m^2)	Allowable bearing capacity (kN/m^2)
Al-Hillah	Hillah	1	1-1.5	5	50
			1.5-2.5	10	100
	Kifil	2	1	7.5	75
			2-3	10	100
Al-Qasim	Talyaah	1	1	7.5	75
			2-3	10	100
	Qasim	2	1-2	6	60
			2-3	10	100
			3-4	13	130
Al-Hashimiyah	Medhatyah	1	1-2.5	4	40
			3-3.5	6	60
			4-5	8	80
	Shomaly	2	1.5-2.5	6	60
Al-Mahawil	Imam	1	1-1.5	5	50
			1.5-2	6	60
			3.5-3	10	100
	Neel	2	1-2	7	70
			2-3	12	120
Al-Musayiab	JurfAl-Sakhar	1+2	1-1.5	7	70
			2-3	10	100

Table 4 Natural moisture content and the cohesive layer at each site.

Qadhaa	City	Borehole site No.	Natural moisture content	Cohesive layer
Al-Hillah	Hillah	1	Closer to the plastic limit than to the liquid limit	Tends to be over consolidated and with a medium to very stiff consistency
	Kifil	2	Closer to the plastic limit than to the liquid limit	Tends to be over consolidated and with a stiff to hard consistency
Al-Qasim	Talyaah	1	Closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a stiff to hard consistency
	Qasim	2	Closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a medium to hard consistency
Al-Hashimiyah	Medhatyah	1	Closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a soft to stiff consistency
	Shomaly	2	It is closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a soft to hard consistency
Al-Mahawil	Imam	1	It is closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a medium to very stiff consistency
	Neel	2	It is closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a medium to very stiff consistency
Al-Musayiab	JurfAl-Sakhar	1+2	It is closer to the plastic limit than to the liquid limit	Tends to be over consolidated, with a stiff to hard consistency

Table 5 Summary of the soil compositions of sites and their material characteristics.

No.	Layers	Classification		Total porosity	Field capacity	Permanent wilting point	Saturated hydraulic conductivity	Thick (m)	GWT (m)
		USDA	USCS						
Al-Hillah City-Al-Hillah Qadhaa									
1	Fill material	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	0.5	2
2	Silty clay + gypsum	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	2	
3	Clayey sandy silt	CL	CL	0.464	0.310	0.187	6.4×10^{-5}	0.5	
4	Silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	6	
5	Silty SAND	LS	SM	0.437	0.105	0.047	1.7×10^{-3}	1	
Al-Kifil City-Al-Hillah Qadhaa & Al-Talyaahcity-Al-Qasim Qadhaa									
1	Sandy silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	7.5	4
2	Clayey silty sand	SL	SM	0.453	0.190	0.085	7.2×10^{-4}	0.5	
3	Silty clayey sand	LS	SM	0.447	0.118	0.065	1.4×10^{-3}	2.5	
Al-Qasim City-Al-Qasim Qadhaa									
1	Fill material	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	1	2.5
2	Silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	0.5	
3	Clayey silty sand	SL	SM	0.453	0.190	0.085	7.2×10^{-4}	0.5	
4	Sandy silty clay & silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	8	
Al-Imamcity-Al-Mahawil Qadhaa									
1	Fill material	L	ML	0.419	0.307	0.180	1.9×10^{-3}	0.5	2.7
2	Clay	C	CH	0.378	0.371	0.265	1.7×10^{-5}	9	
3	Sandy clayey silt	SiCL	SC	0.471	0.342	0.210	4.2×10^{-5}	0.5	
Al-Neel city-Al-Mahawil Qadhaa									
1	Silty clay + sandy silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	10	2.1
		SiC	CH	0.479	0.371	0.251	2.5×10^{-5}		
Al-Medhatyah City-Al-Hashimiyah Qadhaa									
1	Fill material	SC	SC	0.430	0.321	0.221	3.3×10^{-5}	1.2	3.8
2	Sandy silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	0.5	
3	Sandy clayey silt	SiCL	SC	0.471	0.342	0.210	4.2×10^{-5}	6.3	
4	Sandy silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	2	
Al-Shomaly City-Al-Hashimiyah Qadhaa									
1	Fill material	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}	0.7	4
2	Silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	6	
3	Sandy clayey silt	SiCL	SC	0.471	0.342	0.210	4.2×10^{-5}	1	
4	Silty clayey sand	LS	SM	0.447	0.118	0.065	1.4×10^{-3}	1.3	
5	Clay	C	CH	0.378	0.371	0.265	1.7×10^{-5}	1	
Jurf Al-Sakhar City-Al-Musayiab Qadhaa									
1	Silty sand	SL	SM	0.453	0.190	0.085	7.2×10^{-4}	2	10
2	Sandy silty clay	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	7	
3	Dense silty sand	LS	SM	0.437	0.105	0.047	1.7×10^{-3}	1	

6. Conclusions

The present study aimed to conduct soil investigations as part of the selection process for the best sites for landfill in each Qadhaa in the Babylon Governorate. GIS software and multi-criteria decision making methods were used to determine suitable sites for landfill from within the final output maps of suitability index for landfills and which had been implemented in previous studies. Each site was subjected to field soil tests to find the composition of the soil strata at each site to a depth of 10 m, and these results were compared with the soil properties that were adopted for final site selection. The Iraqi Ministry of Housing & Construction, National Centre for Construction Laboratories and Research Babylon, Iraq, carried out the analytical work on the soil in 2016.

The results of the soil investigation at these sites include a determination of the soil profile for each site, the chemical properties, the allowable bearing capacity; Atterberg limits test results and the material characteristics of the strata. In addition, the level of groundwater depth at each site was ascertained.

In Al-Hillah City, Al-Hillah Qadhaa, there are five layers that include fill material (0.5 m), silty clay (2 m), clayey sandy silt (0.5 m), silty clay (6 m) and silty sand (1 m). There are four soil layers at both Al-Kifil City, Al-Hillah Qadhaa and Al-Talyaah City, Al-Qasim Qadhaa, and these layers consist of fill material (1 m), sandy silty clay (6 m), clayey silty sand (0.5 m) and silty clayey sand (2.5 m). The composition of the four soil layers from Al-Qasim City, Al-Qasim Qadhaa are fill material (1 m), Silty clay (0.5 m), clayey silty sand (0.5 m), and sandy silty clay & silty clay (8 m). In Al-Imam City, Al-Mahawil Qadhaa, the three soil layers include fill material (0.5 m), clay (9 m) and sandy clayey silt (0.5 m), whilst at Al-Neel City, Al-Mahawil Qadhaa, the soil consists of silty clay and sandy silty clay (10 m). The soil composition in Al-Medhatyah City, Al-Hashimiyah Qadhaa, includes fill material (1.2 m), sandy silty clay (0.5 m), sandy clayey silt and clayey silty sand (6.3 m), and sandy silty clay (2 m). For Al-Shomaly City, Al-Hashimiyah Qadhaa, the five soil strata are fill material (0.7 m), silty clay (6 m), sandy clayey silt (1 m), silty clayey sand (1.3 m), and clay (1 m). The soil compositions in Jurf Al-Sakhar City, Al-Musayiab Qadhaa, are silty sand (2 m), sandy silty clay (7 m) and dense silty sand (1 m).

The results of the chemical tests for the soil and water samples, at all sites, showed that the maximum contents of sulphate, chloride, gypsum total soluble salts and organic materials were 22.5%, 0.57%, 0.568%, 51.4% and 4.71%, respectively, whilst the minimum contents were 0.04%, 0.0177%, 0.11%, 0.21% and 0.11%, respectively. For water samples, the maximum sulphate content was 389.6 mg/L, while the minimum sulphate content was 61.9 mg/L.

The allowable bearing capacity at different depths below G.S. for all sites varied from 5 to 13 t/m^2 or (50-130) kN/m^2. For all sites, the natural moisture content was closer to the plastic limit than to the liquid limit, whereas the cohesive layers generally were tending to be over consolidated. The cohesive layer was medium to very stiff consistency in Al-Hillah Al-Imam, and Al-Neel; stiff to hard consistency in Al-Kifil Al-Talyaah andJurfAl-Sakhar; stiff to hard consistency in Al-Qasim; medium to hard consistency in Al-Medhatyah; soft to hard consistency in Al-Shomaly.

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Place, Architecture Design and Thermal Comfort: A Municipal Day Care Childhood Center in Colônia Z3, Pelotas/RS, Brazil

Paulo A. Rheingantz[1], Eduardo G. da Cunha[2], Jaqueline da S. Peglow[2], Viviane Ritter[3], Luiza C. Quintana[2], Thalita dos S. Maciel[2], Carolina Beltrame[2], Carolina de M. Duarte[2] and Antonio C. B. da Silva[2]

1. Post-graduation Program in Architecture and Urbanism, Federal University of Pelotas, Pelotas, RS, 96010-020, Brazil;

2. Department of Construction Technology, Federal University of Pelotas, Pelotas, RS, 96010-020, Brazil;

3. Federal Institute Sul-rio-Grandense Campus Pelotas Visconde da Graça, Pelotas, RS 96010-020, Brazil

Abstract: This article reports the discussion about the multiple relations between architectural design and "place" using two different approaches in order to characterize the interfaces of design challenges. The first is qualitative, highlighting the lack of dialogue between the standard-project architecture, the guidelines recommended by the COEDI (Coordenação Geral de Educação Infantil (General Coordination of Early Childhood Education)) of the Ministry of Education, socio-technical and cultural-environmental context and pedagogy. The second, more quantitative, addresses the problems generated by dissociation between the constructive solutions and the bioclimatic demands of different insertion contexts of architectural design in the Brazilian Bioclimatic Zone 2. Initially planned to use a conventional building system, it was transposed to the Wall System, developed by MVC Componentes Plásticos Ltda. The simulation evaluates and compares the level of thermal comfort of the building with two envelope systems. The study reports the analysis of the thermal comfort of a Type C unit, based on thermodynamic simulation, through the software Design Builder (version 4.2.0.054). The analysis of the building simulation results was based on the adaptive comfort model ASHRAE 55/2010. Later, three optimization measures of the thermal comfort level of the building were tested, based on thermal insulation and absorptance coverage, in addition to sun protection system design for the window frames. Preliminary results for the level of comfort of long permanence environments indicate a low level of thermal comfort, the 50% in MVC system and around 60% in the conventional system, and also that the greater discomfort comes from the heat. Based on performance optimization measures of building, the MVC system reached 66.4% of thermal comfort compared to 62% in the conventional system. The results show the importance of adapting the standard project to the local climatic context.

Key words: Place, architectural design, thermal comfort, energy modeling, child education.

1. Introduction

This paper starts from a research conducted at the Post-Graduation Program in Architecture and Urbanism at the Federal University of Pelotas (PROGRAU-UFPel), which is aligned with the STS (science-technology-society) studies and their questions about the universality of "scientific facts", which disconsiders the places or localities where knowledge is produced. It is also aligned with the STS assumption that ideas and discoveries are local or located and situated productions [1].

In this perspective, it is not possible to consider places and buildings, even though they are situated and located, as "fixed things of material nature" [2].

Even after they are built and occupied, places and buildings must dialogue and function together or in co-production with their "users" [3] and contexts. Since they must be recognized, equipped and host specific activities, their qualities do not pre-exist: they emerge from multiple association processes [4]. This

Corresponding author: Paulo A. Rheingantz, Ph.D., architect; research fields: architecture design, environmental perception, and post-occupancy evaluation. E-mail: parheingantz@gmail.com.

way, buildings and places must be understood as "objects", whose specific duplicity makes them both singular—with a stable location and form—and able to host different activities relatively easily. Once they are "ready to be used" at the same time as they are "subject to future modifications", it is possible to qualify them as almost-technologies [5] or as unstable technologies, engaging "technical", "political" and "economic" entities which perform situated knowledge [1]. Places and buildings can be also recognized as a set of relationships between "users" that are human and non-human, which include values, sensations and conceptions related to the physical-formal features and to the activities and actions that are developed therein.

Thus, in this work, buildings and places are thought as interfaces or connections with their users and contexts and together with the movements and transformations produced from such connections. In the same line of reasoning, architecture project is understood as an ongoing process that does not have a definitive formulation, whose movements are permeated by circularity, instability and subjectivity. Its continuity does not end with the conclusion of projects or their construction and its quality comes from a collective effort that is complex, creative and strongly dependent of people, organizations and processes involved in its production and in its action or usage. Because it is inevitably and concomitantly a technical, social and aesthetical process, that is apparently engaged in a "technical" orthodoxy and in an "aesthetical" freedom, its quality is difficult to be explained, once it transcends technique and aesthetics, requiring knowledge that is different from most areas of expertise.

In this perspective and understanding architecture project as a continuous conception process that is inseparable from the intentions of the authors, whose common praxis paradoxically stabilizes uses and technologies and disregards an interpretative flexibility [6, 7], this article aims to: (1) explore possibilities and alternatives to improve the quality of the projects and the environment performance of the Municipal Day Care Childhood Center (EMEIs—initials from Brazilian denomination *Escola Municipal de Educação Infantil*, adopted to replace the world "*creche*", which carried a stigma because it referred to charity institutions) in the city of Pelotas, Brazil, emphasizing on those with the standard-project by the FNDE (*Fundo Nacional de Desenvolvimento da Educação*, National Fund for Education Development in English) for the *Pro-Infância* (Pro-Childhood) Program of the Ministry of Education. This program was created in 2007, to provide financial assistance to municipalities, for building children's schools, with standardized architecture projects and financing for construction, furniture and equipment, as well as technical-pedagogical support and for new enrolments [6]; (2) contribute to overcoming: (a) limitation and inadequacy of an education concept that is not creative regarding spaces and climate [8]; and (b) a school architecture that does not question the relations between conception and organization of the environment, educational practices and today's social demands, producing schools that are almost identical through time and space [9].

Contradicting the recommendation that "the conception of the project must be preceded by participative process involving the educational community" from the reference document of the basic infrastructure guidelines for Day Care Childhood Centers [10], whose "goal is to achieve the accomplishment of the constitutional precept of administration decentralization, as well as participation of several social actors engaged in children education" (authors' translation) [10, 11], the pattern-designs for the EMEIs do not result from a dialogue with educators and children about the buildings where they will share their education experiences, nor from teaching-learning practices, dimensions, proximity or position of diverse environments, and even less from children's demonstrations in games, actions or talks about what they would like to have or to do in their school environments. They respond to the goals and objectives of the *Pro-Infância* Government Program, with projects conceived as closed packages with government prints or brand and despising the contextual differences and the cultural values of the communities. Important issues such as health and disposition of little children, educators and workers in their daily activities, environmental quality and thermal comfort were left to a secondary place.

Lastly, it is important to highlight that the structure and the content of the sections presented hereon do not follow an artificial compartmentation of contents into theoretical foundation, methodology and analysis. This option is grounded on the assumption that humans have a fundamental ability to gather what is apart [10, 11], or so to say, knowledge is built along the process or action of producing it [2, 12-15]. In this sense, it is about the dynamics of a progressive process of knowledge production by a body or "interface that learns" [16] whose mediation is sensitive to the differences that are produced and that is more easily described as one learns to be affected by other elements or actors. This option enables to outline what Whitehead called a "nature's bifurcation" [16], which separates the world and science, things and subjects and then stops "what things really are" [16]: a world of things-and-subjects.

2. Considerations on the Conception of Buildings to Receive Early Childhood in Brazil

Up to 1988, children education in Brazil has prioritized guarding children and most of the day care centers received poor children. Services were not worried about children's rights and most of the day care centers were adaptations of existing buildings, with poor infrastructure and habitability. They were some kind of "children warehouse". From 1988 on, children education becomes a state duty, access to education for all children from 0 to 6 years of age becomes a right and responsibility of municipalities. However, the discussion about architecture for children education in Brazil is still limited to recognizing the importance of the pedagogical organization of the space [17], without exploring its potential as an interface for educational practices.

Instead of prioritizing children, pedagogical practices and the relationships that are produced in its environments, the "traditional" conception of architecture for children education prioritizes public policies and the agency of building designers and producers. Among architects, beyond the idea of rationality, economy and functionality, prevail the issues of organizing day care centers and what they offer to little children as if pedagogical practices and little children were all the same. They do not know that children need different times to learn and to relate; that they only take advantage on the situations if they are available and sensitive for it [17]. They also do not ask what pleases or interests children [18]. Even though they are physically present, little children are ignored, "made invisible" [19]. The adult-centered [20] or adult-morphic [20] point of view of those who design the EMEIs treats little children as incomplete or beings "to-be" [21], denying that little children are complete human beings. In order to break with such process, it is necessary that all those involved in children education learn to dialogue with little children as "subjects full of rights and with singular stories" [22], with the communities they come from and with those who educate them.

The organization of the day care center spaces strengthens the intention of control and surveillance over little children's actions [23], instead of playing a role of challenging and welcoming autonomy, freedom and the spirit of childhood. In this conception, still preponderates a logic of discipline, which keeps little children in an artificial immobility, which stops or makes it harder for them to interact. To make spaces challenging and welcoming, it is necessary to think the organization of day care childhood centers over. Since architects rarely speak to the education staff, there is no conversation between the architecture and pedagogical projects and its materiality is not connected to the educational management nor to the school ground [22]. In general, conversation is limited to make normative restrictions compatible with political interests and technical beliefs of those who design, supervise and keep EMEIs. Due to that, most of the public day care early childhood center designs become outdated devices, old-fashioned and maladjusted to the routine of little children education—pedagogical practices and contents, students' interests and demands. There is almost no space for the new or to question about possibilities or educational potentials of its materiality. The same happens regarding the subjectivities that emerge from the social-cultural-environmental diversity of schools and the urban sites where they are built. Since most of the decision-makers and the designers have never attended a day care centre, there are no reliable guidelines or models of support environments for little children out of their houses [24]. With that, the "a priori" conception of buildings and environments to receive little children is a projection of their authors' dreams and fantasies, and not those of the children they are designed for [25].

3. Considerations about the Designers' Task for the Municipal Early Childhood Education Centers (EMEIs)

An EMEI project should start from the assumption that little children do not go to school because of their own choice or wish. Most of the time, they are put apart from the contact with the environments and the people that they know, trust and depend on [26]. When they are moved away from their familiar environments, they need to build their sense or expectations, comprehension and love for life, based on the environment, space, colors, materials and furniture in the EMEIs [23, 24, 26].

So, to project healthy buildings and places, that are inviting and challenging for little children [10], implicates in: (a) question every choice or decision and their impact on children's well-being; (b) avoid that places and buildings are opposed to the ones experienced by the children; (c) search for the best possible result with the limited resources available. It means to say "no" to everything that reduces or excludes the spirit of childhood, keeping in mind that the perception of objects for a little child is not gestaltic nor configurational, but a non-differential reality, that is inaccurate and mingles the limits between objective and subjective, in a reality that is filled with an emotional flow of affections. Yet for the child, such reality is not as chaotic as it may seem for an adult, the same way "a dream is not chaotic for the one who dreams in the moment he is dreaming" [26].

The built environment of EMEIs should serve as an interface of a field of search for co-production relations, established by the little children, their immediate surroundings and the different subjacent spaces of these relationships, such as: spaces between-objects-and-people, affective space, space of our actions, postural space, mental space, games space [23]. It should operate as an agent that invites educators and little children to organize spaces for wandering, deriving and dreaming actions in each context [23]; as a vital surrounding or projection that involves the child, a landscape laboratory [23] or space-time created by the rhythm of actions and the dialogue between the experience of space and objects. Each EMEI should be conceived as an interface that is made of welcoming environments, challenging and stimulating little children's expression, where they will grow, and that will also be influenced by them. These environments should be seen as "game boards" that invite little children to explore their possibilities and produce actions and feel emotions as they learn, transform, find and symbolize [27].

4. EMEI Colônia Z3

As an attempt to connect knowledge related to a socio-technical approach (qualitative and subjective) and an assessment of the level of thermal comfort—more quantitative and objective—at an EMEI with an FNDE standardized project Type "C", to be built in the Brazilian Bioclimatic Zone 2, we chose the EMEI Colônia Z3, a fishermen village in Pelotas, RS, Brazil (Figs. 1 and 2). It is in a rectangular lot of 35 × 45 meters and maximum declivity of 3%. FNDE's

Fig. 1 Location of Colônia Z3.
Source: edited by authors on Google Earth map.

Fig. 2 EMEI Colônia Z3 Lot.
Source: edited by authors on Googleearth map.

standard projects for pro-childhood EMEIs were initially conceived as a conventional construction system—reinforced concrete structure, walls with 8-hole ceramic brick, double-face plaster, roof with ceramic tiles and ceiling with plasterboard. Because of the delays due to the difficulties with legalization and bidding, they have been adapted by FNDE, in order to use the Wall System developed by MVC Componentes Plásticos Ltda.—foundations in reinforced *radier* concrete, structural walls composed of PVC profiles filled with self-compacting concrete, yard covered with metallic profile "H" structure; internal partitions with panels of EPS (expanded polystyrene) and plasterboard and finishings in reinforced plastic, roof with cement tiles and ceiling with plasterboard panels with finishings in reinforced plastic and yard covered with metallic structure and trusses and metallic thermoacoustic tiles. Evaluation also considered the original conception of standard projects Type "C", to compare both performances.

The pattern design Type "C" can receive up to 120 children from 0 to 6 years of age in two shifts or 60 children in full-time. The Memorial [28] text goes against common sense when it states that its conception which is closed, inflexible and indiscriminately the same for the whole national territory, considers the environmental, geographical, climatic and demographic "great diversity", as well as each region's socio-economic resources, cultural contexts, physical, psychological, intellectual, social and development needs of a generic naturalized little child. It does not mention pedagogical practices and the naturalization of the comprehension of "child" becomes more evident when it states that the design's main goal is to attend to its main user, the little child.

Among the criteria to ensure users' comfort, health and safety, it indicates: easy access between blocks, physical safety that restrains access of unaccompanied children to areas like kitchen, laundry, water castle, central gas, light and telephone; circulation between continuous floor blocks without steps, ramps or joints; environments for integration and living together for children of different ages—yards, solariums and external areas; equipped dimensioned for little children. Such criteria are independent of construction techniques and materials. The description of implementation guidelines strengthens the lack of relation between intentions and project, such as: adequacy of the building to environmental guidelines and regional climate, searching for optimal orientation of the building regarding the apparent movement of the sun and the dominant winds (Figs. 3 and 4).

The same things happen regarding functional and aesthetical guidelines: architectural program drawn up for number of users and "operational daily needs" of the day care childhood center, allowing a complete educational experience, adequate to the age; sectorization of the functional sets in blocks distributed to predict the interaction of the little child with the natural environment; volumetry defined by the blocks dimensioning and the type of coverage assures the visual identity of the project and the *Pro-Infância* Program.

It also states that some elements, like porches, volumes and frames and indoor environments, were thought from the little children's point of view—again naturalized and homogenized. In what concerns colors and finishings, more generalities: use of playful colors, related to users' age (Figs. 5 and 6). Differently of what is suggested by the Memorial [28], the architectural program disregards specific needs of the users of each EMEI and the balance with climate conditions. It naturalizes local conditions and socio-cultural values and standardizes future users. The choice of construction system privileges execution speed instead of important features like easy maintenance, substitution of components and behavior of the materials used in the several stages. Choosing an unconventional construction system that is not well-known in the region and that has never been used for building EMEIs and is produced by only one company, which owns the property rights, with real

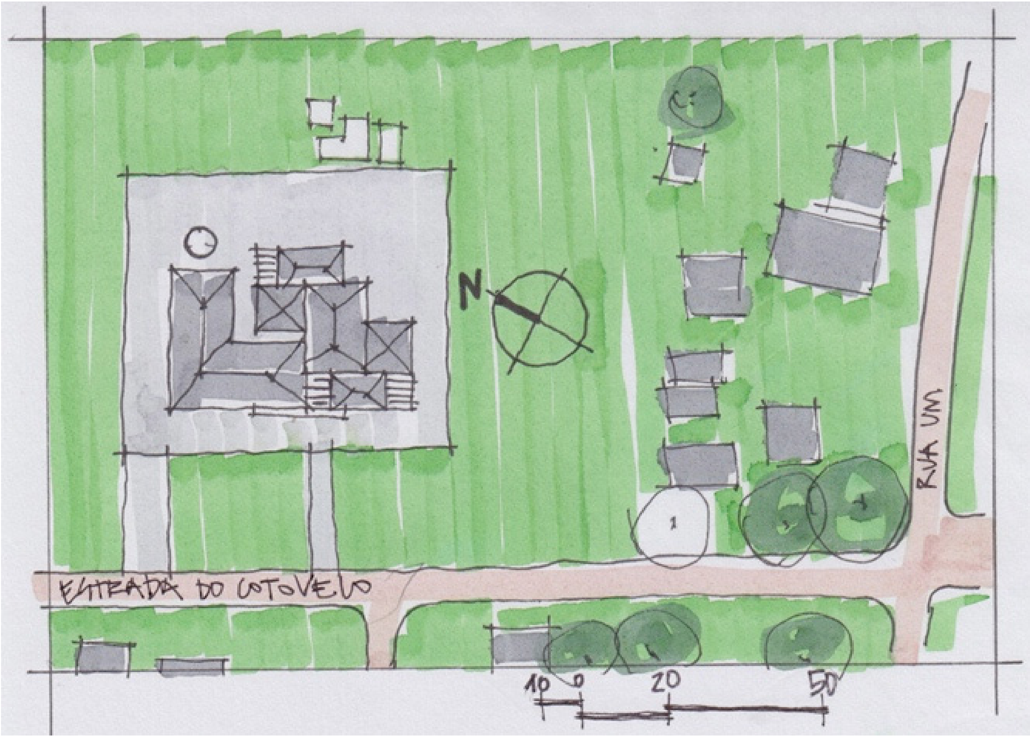

Fig. 3 EMEI Colônia Z3—location.
Source: the authors.

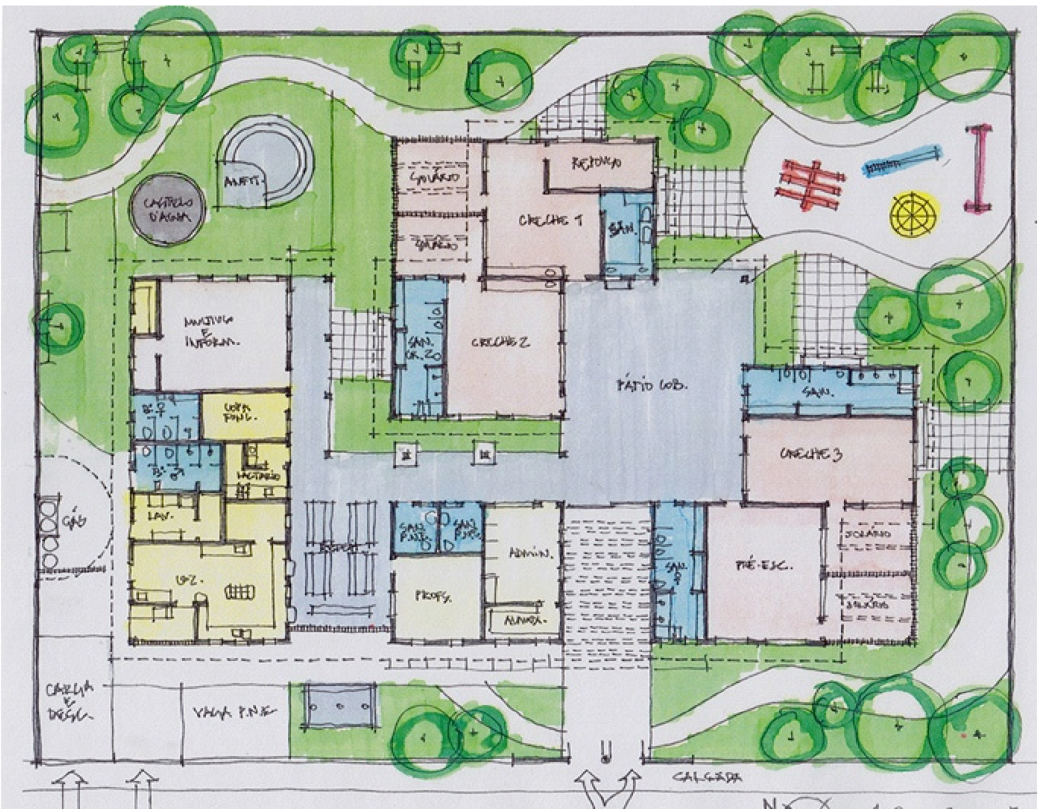

Fig. 4 EMEI Colônia Z3—plan.
Source: the authors.

Fig. 5 EMEI Colônia Z3—SW façade.
Source: the authors.

Fig. 6 EMEI Colônia Z3—NE façade.
Source: the authors.

durability and performance when facing climatic, environmental and usage conditions does not attend the principles of sustainability neither favors identification of the local population with the building.

Transposition to the ground (Figs. 3 and 4) exposes some contradictions with the promises of the Memorial [28]: the blocks of Day Care III and pre-school (SW and SE squares) are a problem in the cold season, and the ensembles of yard-eating place and covered yard-hall-main access make a channel for the dominant wind (NE). Every external window of the blocks designated for children demand external elements of protection from direct sun radiation (*brise-soleils*, *cobogós* or rolling shutters). As it already happens at the EMEI Vera Sass [29], the proximity of the covered yard to the four activity rooms may produce excessive noise, making it hard for children to rest [30].

5. Methodological Strategies

Even though they have been addressed together during research, predicting a possible and probable unfamiliarity of the readers with the background and practices of the STS studies, the methodological strategies, findings and contributions from qualitative and quantitative approaches and their multiple relations with the EMEI project are hereon presented separately.

The quantitative approach emphasizes the level of thermal comfort in the internal spaces for long-time occupation in the original project and the effects of the optimization measures for the building's thermal performance, by using energy modeling as a research strategy. To assess thermal comfort, the thermodynamic simulation of the EMEI was divided into three stages: modeling, simulation and result analysis, using the two construction systems indicated by FNDE: the MVC system, with wall composed of boards of GFRP (glass-fiber reinforced plastic), plasterboard, extended polystyrene—indicated for the construction of the EMEI Colônia Z3, and the conventional system, using masonry with 8-hole ceramic coated bricks, ceramic tiles and the same ceiling of the MVC system—used in the first constructions of EMEIs of Types "B" and "C" and in the standard projects Types 1 and 2. Optimization measures of thermo-energetic performance using opaque and transparent closings (in the ceiling) were tested in both systems. The level of thermal comfort at the EMEI Colônia Z3 was assessed through computer simulation using the DesignBuilder software, considering the building as naturally ventilated. As an indicator of level of thermal comfort in indoor environments, we used adaptative comfort by ASHRAE 55 [30]. Besides evaluating the level of thermal comfort of indoor environments, we also analyzed optimization measures of the envelope, aiming to improve conditions of thermal comfort and to insert a mixed system of solar protection.

For modeling and configuration of the EMEI Colônia Z3 to be built in the city of Pelotas, located in the Bioclimatic Zone 2 (ZB2), NBR 15.220—3 [31], the following guidelines and procedures have been adopted:

Since Pelotas does not have climate files yet, it was necessary to use the one available for TMY (typical meteorological years) from Santa Maria/RS (BRA_Santa.Maria.839360_SWERA.epw) [30] which is also in ZB2, with time variations in temperature, humidity, direction and speed of the wind and solar radiation.

Opening hours of the school were defined from 7:30 to 17:30.

Observing activities and specific occupation, the long-time occupancy environments were set as "occupied" during the whole time the school is open.

Each one of the EMEI's environments was characterized as a thermal zone.

Configuration of opaque (horizontal and vertical) and transparent closings for both construction systems. (MVC X conventional) (Table 1).

Configuration of usage and occupation conditions considered: (1) the prediction of number of people (adults and children) using each environment; and (2) the different activities they carry out, characterizing each environment's density.

Configuration of the EMEI with natural ventilation was based on the work by Martins et al. [32], using a defined set point for opening windows at 25 ºC. If indoor temperature gets to 25 ºC while the outdoors' is lower than 25 ºC and higher than 20 ºC, windows must be open, to use natural ventilation.

The schedule for operating windows allows natural ventilation of the environments during the opening days and hours (from Monday to Friday, from 7:30 to 17:30). Internal temperature and cooling set point indicate when they need to be open or not.

The lighting system was configured separately for each thermal zone, considering the density of lighting power installed in each environment. These values have been obtained from data from the electrical project and from the result of sum of the power of each luminaire installed divided by the environment's area.

Simulation analyzed the environments' level of thermal comfort. The indicator of thermal comfort used was adaptative comfort by ASHRAE 55 [30], which considers the users' capacity to adapt to the local microclimatic context in a naturally ventilated environment, by operating the opening and closing of windows and doors.

Intending to improve the level of thermal comfort for the "users" of the EMEI, optimization measures for performance in vertical and horizontal plans have been proposed and tested. Since the roof is the building's enveloping element that receives most of the solar radiation along the year, and because of its importance in defining thermal loads, three proposals have been

Table 1 Construction systems of FNDE's standardized project for EMEI Type "C".

EMEI	MVC technology	U (W/m^2K)	Conventional technology	U (W/m^2K)
Walls	Glass-fiber reinforced plastic, plasterboard, extended polystyrene and glass-fiber reinforced plastic	0.55	8-hole ceramic coated bricks measuring 19 × 19 × 9 cm, coated in both faces (14 cm)	2.59
Roof/ceiling	Ceramic tiles, air chamber, plasterboard, extended polystyrene, and plasterboard	1.32	Roof with colonial tiles, air chamber and precast slab	2.48

tested for improving performance: alteration of thermal transmittance of the roofs using an isolation system of mineral wool (thickness of 0.05 m, density of 20 kg/m³, thermal conductivity of 0.045 W/(m·K) and specific heat of 0.75 kJ/(kg·K)) beneath the tiles; alteration of absorptance, changing the ceiling color to white (α = 0.20); and both these proposals together: thermal isolation with mineral wool blanket and painting in white, with the characteristics mentioned above. In the vertical plan, horizontal and mixed (horizontal and vertical) solar shutters have been tested in windows.

6. Weaving Reflections from the Studies of the EMEIS Colônia Z3 and Vera Sass

Two reference documents produced by COEDI (National Coordination of Child Education) [10, 33], recognize the child as a subject of the education process and the main user of educational environment, and both recommend to follow an ensemble of "essential guidelines": sustainability—a harmonious relation with the surroundings and use of construction materials and techniques that value regional reserves—universal and inclusive accessibility; harmonious relation between the pedagogical proposals and the built environment—one that is compatible with the physical, psychological, social and intellectual needs of the children regarding volume, environment, spatial, material, color and texture arrangements [10, 34]. Among other things, these documents request and demand that voice should be given to multiple actors, such as children, families, educators, communities, project designers, climate, regional materials, local workers and technicians and contexts.

Despising the recommendations of flexibility that would allow to adjust implementation to specific conditions [9], FNDE's projects followed a wider program that is standardized and architectural sets that prioritize economy, construction rationality and the government's policies. Just like many other school architecture proposals, such projects function more as a symbol of a government policy [35] than as an answer to specific demands of the physical-socio-cultural context of each unit. For the head of COEDI, even though they are not according to the reference documents [10, 34], FNDE's standardized projects represent a new paradigm for building EMEIs, since they allow: to review and update the EMEIs technical specifications; to redefine the educational environment for childhood; to rule and control the conception, construction and usage of EMEIs on a national scale; and to orientate the EMEIs' supply expectations. This is the same opinion of the staff responsible for accession, inclusion and execution of the Pro-Childhood Program in Pelotas.

Once they were vertically implemented, FNDE's standard projects for the Pro-Childhood Program disregarded a lot of the "essential guidelines" recommended by the COEDI [10, 34], contradicting the assumption that every knowledge is local or situated, making several actors that have been previously mentioned invisible. The rigour of the program, the implementation, the set, the construction system, the form and the aesthetical standards naturalize environments and discredit local peculiarities as well as communities' cultural values.

In another inversion of values, the choice of the lots was only guided by dimensions and topography. Just like the lot choice and the rigour of the program, the implementation of the blocks happened despite the best orientation, according only to the lots' dimensions. The same way, the EMEI Vera Sass, built in 2014 in the city of Erechim, RS, Brasil, also located in ZB2 and with a standard project Type "C", conventional system and capacity to receive 112 children from 0 to 6 years of age full-time, increases the gap between the manual text and the project's lack of flexibility facing real situations. The municipality found difficulties to adapt the EMEI to receive 140 children from 0 to 4 years of age. To receive the 28 exceeding children, it was necessary to adapt a scheme of sharing space by using activity rooms, library and informatics room alternately, for two groups of children—except for the entering, leaving and resting hours. Even though the manual mentions adaptations of the standard project for cold climate—closings for the covered yard, to lower the ceilings of the activities rooms to 2.70 m and to change the granite floor for a vinyl blankets—municipalities must bear the costs. At EMEI Vera Sass, the covered yard received a wood ceiling and was closed with glass, the internal corridor between service and pedagogical blocks was covered. But the granite floor and the 3.00 m height to the ceiling were kept in the activities rooms [31]. The POE (post-occupancy evaluation) carried out by Berleze et al. [31] identified the following problems:

(1) Walkthrough analysi*s*: nurseries—problems with natural lighting (wide windows orientated to the west are impaired by the use of blackout curtains or by craft paper for darkening the environment) and with crossed ventilation (since smaller windows turned to the covered yard are closed to reduce noise, especially during the children's resting time), increasing humidity and discomfort; roughness of the concrete floor in the solariums. Covered yard and eating place—problems with excessive noise due to the use of low absorbency materials that are not compatible with eating places (during meals, children are distracted by toys and by other children's activities); activities and dimensions also produce dust and noise. The indiscriminate use of granite floor produces discomfort due to thermal asymmetry;

(2) Survey with teachers: inadequacy of the floor (91%), undersized resting environments (87%), inadequacy of the stairs for the showers (74%); cold corridors, unprotected during winter (91%); inadequacy of the floor of the covered yard and the eating place (74%), inadequate proximity to the eating place (100%); uncovered yard—inadequate toys (61%);

(3) Visual mapping: problems with the size of the activities and resting spaces, inadequacy of the floor, problems of natural ventilation, bad smell, orientation of the solariums that reduces their use to one shift. Regarding the collective environments, teachers reported problems in the covered yard and in the eating place (layout, cold in winter and warm in summer—in the teachers' opinion, the nursery, the covered yard and the eating place are too warm in Summer, noise and bad smell); outdoor areas (pleasant and well-dimensioned). The authors highlight the inadequacy of the project and the building during the cold season, as it does not plan a coverage for the external corridors between blocks, exposing users to the wind and to the rain [31].

Municipalities found difficulties for regulating the lots' registries and with bidding, due to the discrepancy of the budgets for each EMEI. Among the several requests they must fulfill, municipalities that are enabled for these projects have to choose lots with the dimensions and the characteristics that meet the projects and the property domains and nominate an engineer as technical manager. The land regulation process, the elaboration of the underground analysis services and the foundations projects took around 2 years and a huge amount of the municipality's budget. Pelotas Municipality was called to Brasília in the beginning of 2012, to discuss a review of the unitary cost of the EMEIs, an extension of the execution deadline for the works that had not yet started, the adhesion to the "innovative methodologies" program and to speed up the bidding process through an electronic trading for the RPN (National Prices Registry). Among the advantages presented by FNDE [36], there were: a single call with more quality specifications; lower price; construction agility; cleanness of the works and sustainability. In the offices in Brasília, everything has been properly planned—favorable arguments also based in simulations, once the system had never been used in Pelotas, even less in schools. However, in the real contexts of the cities that had followed FNDE's recommendations—option for RPN bidding system and choice for the Wall System for construction—like

Curitiba, where the company headquarters is located and where performance and durability of the EMEIs in different real conditions and microclimates are still unknown, things did not come up exactly as they were planned, according to the Coordinator of FNDE's CODIN (Infrastructure and Development Coordination).

FNDE concluded the national bidding in November 2013, and Pelotas City Hall has signed new contracts for building 14 new EMEIs with MVC, at the same time as it started the landscaping works and the foundations of the five first ones—Eldorado, Getúlio Vargas, Farroupilha, Z3 and Monte Bonito—as a counterpart, requested by the program. Nonetheless, new difficulties appeared during the works in three EMEIs and were turned into reasons for MVC to delay the installation of the construction sites and start building. The company has never admitted that the delay was due to a negotiation to readjust in 18% the values that have been contracted, under the claim that the costs (estimated in October, 2012) were outdated. The City agreed to bear the increase with its own budget, but the works continued stagnated up to December, 2014, this time due to the bad weather that would be making it difficult to finish construction sites and to start building. By the end of 2015, at the same time as the City disqualified the company, the newspaper Zero Hora published news informing that MVC would be boarding material for building emergency houses to shelter Syrian refugees in Germany [34].

The same way as other proposals of school architecture and despite the recognition by the COEDI and the richness of the program concerning the yard environments and areas, as we mentioned above, FNDE's standard projects for EMEIs function more as a symbol of a government policy than as an answer to the physical, technical, cultural and socio-environmental demands of the places where they are built. There is no dialogue between the EMEI and the context and environment of Colônia Z3: with the rigor of the set, the services block is in the best orientation, disregarding the children's activities rooms. The example of EMEI Colônia Z3 indicated the discontinuity between what is in the project and what is not there… but should be. Such issues point that nowadays, the infrastructure that is needed to comply with the constitutional precept, the guidelines for children education and the quality of the infrastructure of public institutions for children education are still a serious problem [33].

Regarding quantitative issues, the initial results, previous to optimization, indicated: (1) that the conventional construction system shows better performance than the MVC construction system, even though the level of thermal comfort of long-time occupation environments has been low in both systems; and (2) it is necessary to improve the architectural project. Table 2 shows the level of comfort of conventional and MVC systems, respectively.

While the vertical closings of the EMEI with conventional construction system presented an average level of thermal comfort in long-time occupation environments of about 60%, vertical closing with MVC

Table 2 Results of the optimization simulations for EMEI Z3—% of thermal comfort according to ASHRAE 55.

Description of simulations	Conventional System			MVC System		
	Cold (%)	Heat (%)	Comfort (%)	Cold (%)	Heat (%)	Comfort (%)
EMEI Z3 case base	13.7	25.9	60.4	9.3	39.9	50.8
EMEI Z3 + Coverage with 0.2 absorpt.	14.2	24.8	61.0	10.5	33.5	56.1
EMEI Z3 + Coverage with isolation	13.5	25.7	60.8	8.8	39.4	51.9
EMEI Z3 + Coverage with 0.2 absorpt. + isolation	13.8	25.0	61.2	9.4	35.5	55.1
EMEI Z3 + Coverage with 0.2 absorpt. + isolation + brise	15.2	22.8	62.0	12.2	21.4	66.4

System presented about 50%. When considering only occupied hours (from 7:00 to 17:30), the difference was more than 300 hours or about 10 days a year of thermal discomfort due to heat than the best configuration.

While heat thermal discomfort was at about 40% of the hours in the year at the EMEI with MVC System, it dropped to almost 25% of the hours in the year in the conventional system, with coated ceramic masonry. During winter, indoor environments with vertical sealings of coated ceramic brick are approximately 6% colder than the ones with plastic board sealing by MVC System. Placing results in a linear way, it is possible to consider that in the MVC System, there was one month more of discomfort due to heat, compared to traditional system. These first results point to a need for optimization measures for thermal performance of the buildings, aiming to improve the level of thermal comfort of the indoor long-time occupancy environments. Even though the envelope of the MVC System presents more thermal isolation, heat gains from the vertical and horizontal sealings, added to the absence of internal thermal mass, result into more discomfort due to heat. As for the conventional system, it is possible to notice a constant performance, with little variation: the building with the painted ceiling obtained a level of thermal comfort of 61.1%, while thermal isolation corresponded to 60.8%. Together, painting and isolation of the ceiling represented 61.2%. Finally, painting and isolation with brises led to a thermal comfort level of 62.0%.

In order to optimize the level of thermal comfort of EMEI Colônia Z3 in both construction systems (MVC and conventional systems), two possible measures for thermal comfort in long-time occupation environments have been tested. The first one, regarding the horizontal plan, with alteration of the absorptance and isolation of the ceiling; and the second one, regarding the vertical plan, by inserting mixed solar protectors. At first, painting the ceiling in white was tested. Considering both construction systems, the level of thermal comfort in the long-time occupation environments increased around 1% in the conventional system and 4% in the MVC one. In the specific case of thermal isolation of the ceiling, an increase of 1% was observed in the hours of thermal comfort inside the building, which means an addition of 30 hours in the year. The simulation with a combination of both solutions and increasing thermal isolation of the roof by painting the tiles in white resulted into an improvement of 5% in the MVC System, or an addition of 150 hours of 15 days of thermal comfort along the year, considering the school’s opening hours. For the conventional system, with wall in ceramic masonry, improvement was at about 1% or 30 hours. The inclusion of protectors from the Sun increased thermal comfort in the MVC System by 15%, or an addition on 450 hours or 45 days of thermal comfort for the users of these environments, which characterizes a significant change. In the conventional system, the alteration was only 1%.

7. Final Considerations

Firstly, it is necessary to reassert the influence of FNDE’s pattern designs in the comprehension of the infrastructure needed for children education, without forgetting that its conception and unilateral adoption disregarded important points like dialogue and the relation of co-production with little children, educators, families and communities. Also, it conceives “users” and EMEIs as separate things and suggests the existence of an essential usage, which is naturalized and deductible from the EMEI itself, independently of who its “users” are and how these “users” are and that EMEIs interact. How are “users” defined and by whom? How do project designers think the users? Who speaks for users and how [37]? These questions remain open. The arguments in the Manual text indicate an old-fashioned conception of “users”, as generic, passive and adaptable beings. The projects “script” configured future “users” of EMEIs as a homogeneous category and considered issues like gender, age, socio-economic and ethnical differences as irrelevant

[37].

Simulations, on the other hand, showed that the alteration proposed had a stronger impact over the MVC system, with worse thermal performance, approximating the level of thermal comfort of the two alternatives for construction systems. The test with two solutions for optimizing the EMEI resulted in 62% of the opening hours with thermal comfort in the conventional technology; while in the MVC, 66.4%. Optimization did not achieve the 80% recommended by the RTQ-C for naturally ventilated environments, neither the 85% recommended by the level "C" of ISO 7730 [35]. In future works, analysis shall consider the influence of the vegetation in the thermal comfort of the building in controlling direct solar radiation as a project strategy, which is important for producing healthy, inviting and challenging places for little children [10, 36]. It is important to highlight that the project with MVC technology presented low thermal performance at first and after optimization measures, it showed the highest levels among the simulated proposals. Another aspect to consider is the need to review the architectural project, once the best performance of the conventional system is still very low—around 65%, even when all improvements are included. It is recommended that form and configuration of the project are reviewed, taking advantage of the façades with north and south orientation and placing the biggest windows in the north one, to make it easier to control direct solar radiation and dominant winds (NE) in the warm seasons. Simulation allowed to verify that the MVC construction system, with the worst performance, may be the best choice if the project is corrected, by incorporating eaves or porches that protect the walls, windows and doors from direct solar radiation. With simulated project corrections and adjustments, comfort thermal increased from 50% to 66%, corresponding to 45 days more of thermal comfort for users. This study highlighted the importance of the adequate orientation and construction system in architecture projects. Results indicate that it is not enough to only consider the designers' point of view nor to improve isolation of the envelope, if direct solar radiation is not controlled.

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Sustainable Waterfront Development—A Case Study of Bahary in Alexandria, Egypt

Riham A. Ragheb
Department of Architectural Engineering, Faculty of Engineering, Pharos University, Alexandria 21311, Egypt

Abstract: Sustainable waterfront development is about creating a vision for an area and then deploying the skills and resources to realize it after involving a dialogue with the customer within an area. Also, it draws together many strands of place making such as environmental responsibility, social equity and economic viability, planning and transportation policy, architectural design into the creation of places of beauty and distinct identity. The development of waterfronts shapes communities around the water bodies and reflects the ability of cities to adapt to altered economic and social circumstances. The aim of this paper is to identify some approaches for applying sustainable waterfront development. By respecting the quality of life and defining sustainability in a broader context, a case will be made for enhancing the waterfront development, through the place making criteria, analyzing the Bahary waterfront in Alexandria, Egypt. The paper concludes some recommendations to develop Bahary waterfront based on the principles that are collected from the theoretical study in order to well design a waterfront responded to the wishes of the community.

Key words: Place making, quality of life, Bahary, sustainable waterfront development.

1. Introduction

The waterfront is a unique and irreplaceable resource, also, its boundaries are difficult to determine because they are contained mixed use development, which is relatively homogeneous. Thus, it can be characterized as a place integrating land with water and having a natural attraction to people [1]. The waterfronts can be regarded in terms of property that has a strong visual or physical connection to water [2]. Also, waterfront properties may not necessarily need to be directly fronting water but are tied to it visually or are linked to it as a part of a larger scheme [3].

This paper is based on three approaches: theoretical, applied and analytical study. The theoretical study tends to cover the concept of waterfront development, and then identify the sustainable waterfront development such as the sustainable development principles, the quality of life indicators and place making criteria. This is followed by an applied study of Bahary, Alexandria in Egypt, and its context and potentials by the application of the sustainable waterfront development approaches are analyzed. Then the paper concludes the important recommendations to improve this area in order to achieve sustainable waterfront development.

2. Waterfront Development

There are several meanings of waterfront development which vary according to the characteristics of sites and cities. Waterfront development has a number of expressions such as "waterfront regeneration" [4], "waterfront revitalization" [5], and "waterfront redevelopment" [6]. Waterfront development is a process that begins due to the desires of a community to improve its waterfront which contains mixed use development that is relatively consistent.

While, the scale and type of the waterfront redevelopment varies from city to city, the basic concept of development is similar. There are three categories of waterfront development on different levels which help to elucidate the meaning of waterfront development [1]:

Corresponding author: Riham A. Ragheb, lecturer; research field: architecture. E-mail: riham.ragheb@pua.edu.eg.

• Waterside development is local and environmental planning which puts emphasis on the water-human relationship design and the waterfront remedy, and its objective is to create an accessible and enjoyable water environment;

• Waterfront development is urban planning which puts emphasis on the feasibility study of the development projects and the spatial design, and its objective is renewal and development of the urban areas;

• Coastal development is national planning which puts emphasis on the development strategies and the implementation of planning, and its objective is to prescribe the character of the city and the development scheme.

2.1 Importance of Waterfront Development

Waterfronts are a special class of national resource due to their unique potential in affording society diversified opportunities for economic development, public enjoyment, and civic identity. They have become the focus of many issues created by the changing technologies and the pressures of population and commerce. The nature and uses of waterfronts have changed and left large sections of waterfront land unused or under used. Therefore, the development of waterfront areas has become a challenge to affect the identity and environmental quality of cities. Waterfronts have been called romantic and used as places for dreaming and recreation, also waterfronts left the feelings of openness and freedom that tend to be everybody's place. The presence of water in cities is an element of attraction and holds out the hope of a better life.

2.2 Types of Waterfront Development

A city must first and foremost determine what it intends its waterfront to be. These issues must be sorted out before a city can plan for the redevelopment of its waterfront. In a trend of transforming the waterfronts to vibrant zones of leisure, commerce and housing by waterfront development [3], there are a number of conventional types:

2.2.1 Major Waterfront Transformations

Major waterfront transformations are unique that meet the needs and aspirations of cities that are unlike in geography, history and character. They share many factors such as housing, shopping, offices and recreation. There are complex negotiations, dedicated leadership and huge sums of public and private money are involved to accomplish the transformations.

2.2.2 The Commercial Waterfront

There are a variety of project typifies the dynamism of the commercial waterfront to encourage public enjoyment of the waterfront. These projects include "festival marketplace" which is widespread and longstanding tradition of eating, shopping and socializing along water bodies, likewise is a public focal point, drawing people to attend many events.

2.2.3 The Cultural, Educational and Environmental Waterfront

The cultural, educational and environmental waterfront emphasizes the vital connections between people and water and can have a real effect on the way they think about this basic resource which man and natural are inseparable parts of the unified whole.

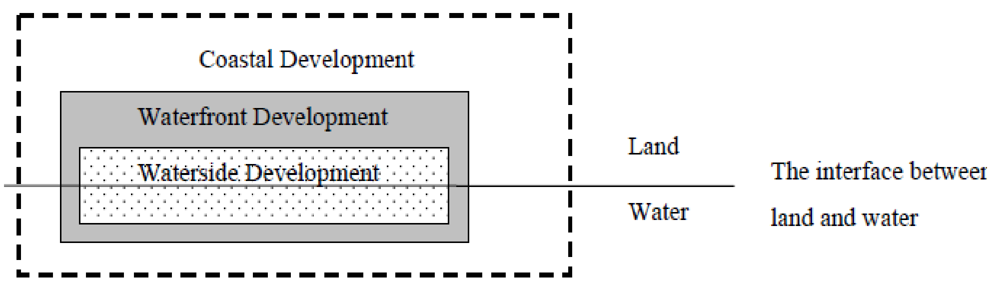

Fig. 1 The three categories of waterfront development [1].

Waterfronts have been providing beautiful setting for religious architecture, memorials, public art and grand cultural institutions and educational sites for generations.

2.2.4 The Historic Waterfront

Instead of condemning old waterfront structures to non-use, decay and ultimate abandonment, some cities are working toward the preservation and adaptive reuse of historic buildings that maintains a tangible sense of the past and favoring a restorative approach that makes for a richer community and captures the allure that comes from being in touch with the past in modern daily life.

2.2.5 The Recreational Waterfront

Spending a leisure time on the water, whether for fishing, swimming or quiet contemplation is the recent theme of the urban waterfront development around the globe. Also, creating public spaces such as parks, marinas, walkways and promenades with shade pavilions, distinctive paving and lighted fountains constitute the biggest change along today's urban waterfront, add a pleasant atmosphere and provide relaxation and enjoyment with being on the waterfront.

2.2.6 The Residential Waterfront

People throughout history have been living along the water for reasons both practical and poetic which housing styles varied according to the culture. Water, rivers, lakes, coasts and canals are public resources; the space along the water's edge is welcoming balanced to visitors as well as to residential population. This means that walkways and facilities are visible, attractive and accessible and comfortable for the residents.

2.3 Waterfront Development Process

The opportunity for the urban waterfront development exists when the difference in an existing property's value and its value in a changed state exceeds the cost of the conversion. Waterfront development process goes through different phases which are [7]:

2.3.1 The Pre-development Phase

The pre-development phase includes project initiation, project analysis, prepares the preliminary design and project packaging toward identifying opportunities for the development. During this phase, it is important to reevaluate the development concept and refine the program in light of changing circumstances and new information, research, comprehensive analysis, and calculations of time range and cost of activities involved to fully realize the development.

2.3.2 The Development Phase

The development process focuses on design, financing and implementation. While these basic tasks transform a project proposal into physical reality, the timing of financial support and the activities of the professional designers and building contractors must be carefully coordinated to produce the project that meets the objectives.

2.3.3 Post Development Phase

The post development activities are determined to extent the long-term viability. Although the managing and maintaining requirements of the waterfront projects are identified before the start of construction, the general trend agreements for public/private development projects must clearly define which party will be responsible for the management and maintenance and who will pay the cost.

3. Waterfront Development Approaches

High quality, well designed and managed urban spaces play a crucial role in promoting wellbeing and contribute positive social, economic and environmental value to cities for any improvement, development and future monitoring. Public open spaces have positive associations with people's quality of life, health, well-being and their feelings. Therefore, a better understanding of the links between the quality of public spaces and quality of life is vital to justify greater development and improving public realm. The public realm is where most of human contact and interaction take place and its character will reinforce the public place. Therefore, it is important to achieve what really matters to people and develop the sense of place by creating a public realm and built environment that are of the highest quality. Also, commercial viability, tourist attractions, livability and sustainability are important factors to take into consideration to provide a better quality of life for the city [8]

Several approaches discuss the benefits of a well designed built environment and its effect on many aspects of daily lives. There are clear denominators that link the different approaches that focus on the human wellbeing. Attractive and open mixed use urban spaces with good accessibility encourage leisure activities and reduce crime and vandalism. Quality of life, sustainability, and place making criteria are a multidisciplinary philosophy incorporating many different fields. They are the process of creating places where people feel safe, happy, and at home. To achieve a great place making, it is necessary to requir sustainability and quality of life criteria which are implemented by various principles. In order to analyze a waterfront case study, it is important to set the following principles to well design a waterfront.

3.1 The Quality of Life Indicators

Quality of life is a relatively impressionistic and a multidimensional concept which means different things to different people [9]. The optimal level of quality of life is produced by combining the physical and psychological inputs. The quality of life can be translated through social and environmental considerations in the process of urban planning and is affected by the place in which we live. The concept of quality of life includes subjective or qualitative phenomena at the individual and the community level as well as objective measures of the status of individuals and the community [10].

The interest in quality of life comes from city leaders and different parties including those who are interested in human development, social development, sustainable development and healthy communities. Thus, quality of life is important because a lot of people and organizations are paying attention to it. There is a concern to measure the quality of life of cities and understand how we are doing and feeling [10].

In the past few decades, social scientists have attempted to objectively measure the quality of urban life through a variety of quantifiable social indicators which have been structured around the social/cultural, economic and environmental wellbeing to maintain and improve quality of life in urban spaces. These indicators are: natural and living environment, overall experience of life, governance and basic rights, health, education, economic and physical safety, leisure and social interactions, productive or main activity and material living conditions [11].

3.2 The Place Making Criteria

Great public spaces are those places where celebrations are held, social and economic exchanges occur, friends meet, and cultures mix [12]. The public places need to be unique, attractive, colorful, related to the human-scale and have different contexts such as historical, geographical, physical or cultural. The places as streets, open spaces or seafronts can be designed visually and functionally, through sensitive and imaginative design to provide a feeling of well-being or comfort [8]. Engineering, architecture, landscape architecture, urban planning, social work, journalism, and public administration have improved the urban physical environment to incorporate knowledge and ideas acquired from the social and physical sciences on dealing with some of the social problems associated with urbanization [13]. Therefore, the process of place making allows diverse constituencies to identify how public spaces can be shaped to make them welcoming, well-functioning and attractive places for people. One of the most critical factors in achieving a public space that truly serves its constituents, improve the daily experience and draws people time and again, is by asking people about their concerns and wishes and allowing them to influence decision-making about that space.

More than just promoting better urban design, place making strengthens facilitates creative patterns of use, paying particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution. According to public spaces which are a nonprofit planning, design and educational organization, public spaces have four major attributes to evaluate a place and measure its success which are: access and linkages, uses and activities, comfort and image, and sociability [12]:

3.2.1 Access and Linkages

A place has to be well connected to its surroundings visually and physically and easy to get to and to get through. Also, the edges of a space are important as well and the place has to have a high parking turnover which is convenient to public transit [14].

3.2.2 Comfort and Image

The key of a successful space is to be comfortable and have a good image. Comfort includes perceptions about safety, cleanliness, and the availability of places to give people the choice to sit where they want [14].

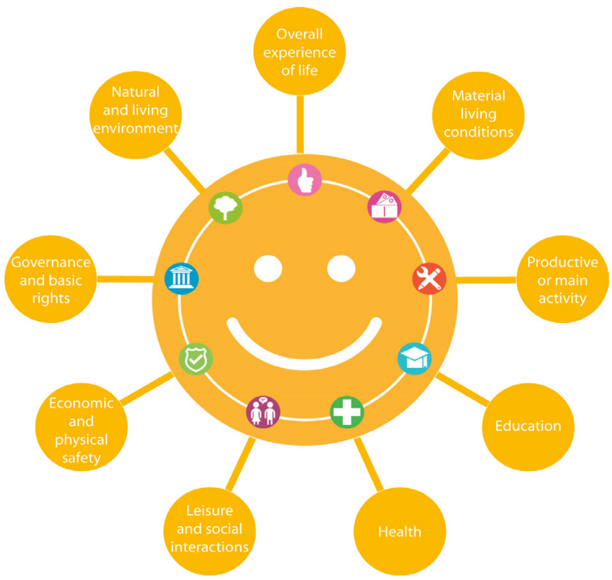

Fig. 2 The quality of life indicators [11].

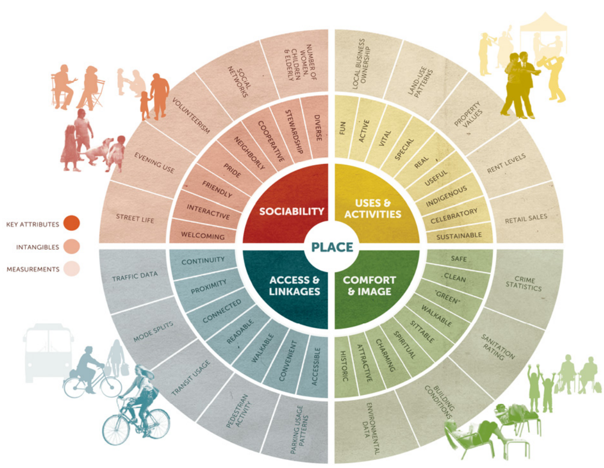

Fig. 3 The place making criteria [12].

3.2.3 Uses and Activities

Uses and activities are the basic building blocks of a place. Having some activities to do in the place gives people a cause to come and return. It is important to provide various well managed activities throughout the day for people of different ages, to be used by singles or people in groups [14].

3.2.4 Sociability

When people see friends, meet their neighbors, and feel comfortable interacting with guests, they tend to feel a stronger sense of place or attachment to the place that fosters these types of social activities. This is a difficult quality for a place to achieve, but once attained, it becomes an unmistakable feature [14].

3.3 Sustainable Development Principles

Sustainable development projects are a key component of the transformation of urban environments. In such urban environments, waterfronts present themselves as a very particular case. The declining and neglected waterfronts constitute highly potential targets for transformation into new and refined patterns of land uses through the development projects while aiming for a high quality of life, nourishment of business and conservation of the environment. Waterfront development schemes necessarily involve the principles of sustainability: economic, social, environmental, and preservation [3].

3.3.1 Economic

The deindustrialization of city centers has resulted in many changes in technology, and thus has caused many industrial places and ports to relocate. Some cities shift their industrial places and activities from cities to suburbs. This relocation has left the existing waterfronts land freed up for development.

3.3.2 Social

The global culture today requires more open spaces for recreation and physical needs. Generally, more mobility has caused an expansion of tourism. This may encourage the installation of new mixed uses along the water bodies that combine areas of open space and leisure, with shops, café and restaurants and provide cultural and recreational attraction.

3.3.3 Environmental

Since the 1970s, there has been an emphasis on the environmental issues that include cleaning up water bodies, water supply, natural marine life and pollution. This demand is to protect the environment, and encourage new waterfront investment.

3.3.4 Preservation

The trend toward cultural tourism pushes to make value to the historical building. Preservation and restoration are important to give a character to the city. The similar element in waterfront development around the world is the public's desire to be near to the water. Most existing waterfront areas which have not yet been discovered are either remains of industrial areas and slum areas. These areas may become fashionable places to live in, and can promote more investments [3]. In dealing with the development of waterfronts, they are classified into three categories [15]:

- The first one is "conservation" which aims to use the site of an old waterfront, which still exists even today, and restores it for the people;
- The second category is "redevelopment", which is characterized by an attempt to resurrect the waterfront as important areas of urban life;
- The third is "development", which is an attempt to create a waterfront which will meet the present needs of the city.

4. The Gomrok District

Alexandria city extends today some 60 km along the Mediterranean coast, but its breadth is limited to an average of 1 to 5 km. It encompassed an area of 2,680 km^2. Residential land use is the most dominant in the urban area, but it is difficult to segregate residential land use from other urban functions. Commerce and workshops are often completely mixed with the residential use. The city of Alexandria is divided into six districts: Montazah District, Eastern District, Middle District, Gomrok District, Western

District and Amriya District.

The Gomrok District with total area of 4 km^2 is considered the smallest area with the highest population density with a rate of increase of 1.17% per year.

4.1 Historical Background

Alexandria was founded by Alexander the Great in April 331 BC, Alexandria became the capital of the Greco-Roman Egypt, its status as a beacon of culture symbolized by Pharos; the famous lighthouse. Dinocrates built the Heptastadion, the causeway between Pharos and the mainland. This divided the harbors into the Western and Eastern [14]. Of modern Alexandria, the oldest section is along the causeway which links what was once Pharos island with the

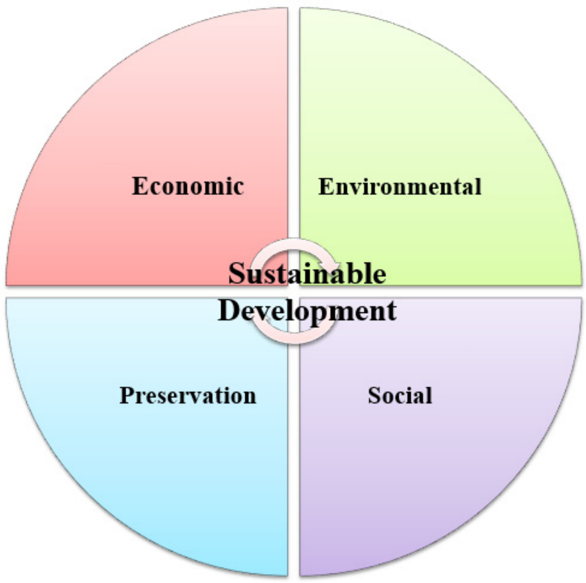

Fig. 4 The sustainable development principles.

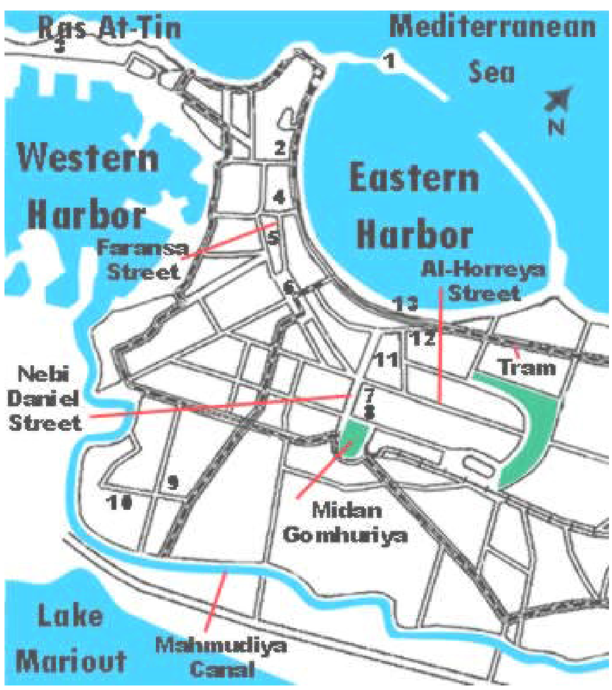

Fig. 5 The map of old Alexandria [16].

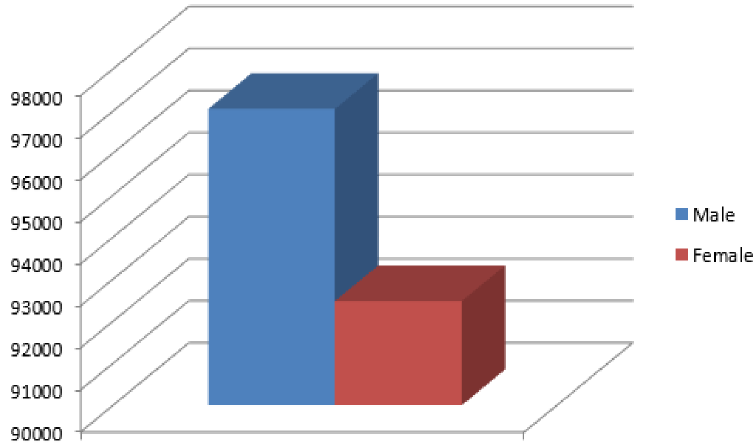

Fig. 6 The distribution of the population.

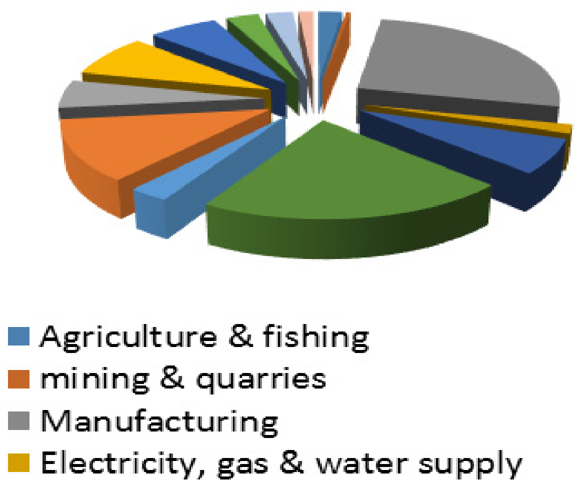

Fig. 7 Manpower studies classification according to the occupations.

mainland and includes the districts of Gomrok that includes Anfushi, and Ras el-Tin that are known to westerners as the Turkish Quarter. The area forms somewhat of a T-shape, dividing the Eastern Harbor from the Western Harbor [16].

4.2 Climatic Conditions

Due to the geographical location for the Mediterranean Sea. The latter has apparently an influential impact as it is related to the enjoyment of the moderate climatic conditions of the study area which is suitable for human life throughout the year.

4.3 Population of the Gomrok District

The Gomrok District is considered the smallest area of Alexandria with the highest density with an area of 622 acres and the current population is 123 thousand people-intensive public 191 people/acre.

4.4 The Land Use of the Gomrok District

Gomrok District is a mixed-use reaching a rate of about 58% residential use and the proportion of economic activities increases the proportion of services for up to about 17.4%. In addition, the existing physical environment is considered a problem due to its degradation and the marine pollution.

4.5 Monuments and Ancient Sites in Gomrok District

There are many monuments and ancient sites. Some of them are highlighted in Fig. 8

5. Bahary Study Area

Bahary waterfront in Bahary, Kasr Ras El Tin, is classified as a main street in the street network of

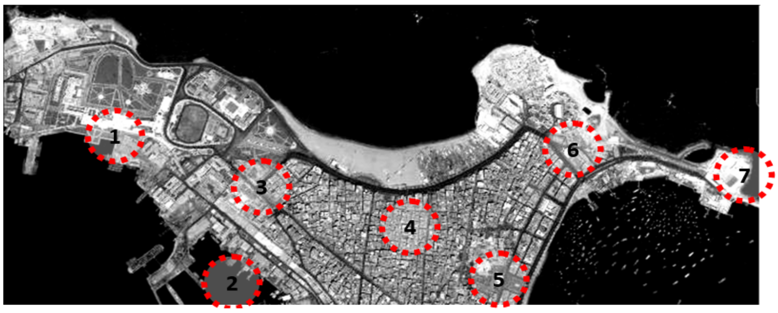

Fig. 8 Map of monumental and ancient sites.

Fig. 9 Pictures of the famous sites by order: Ras El Tin Palace; Alexandria Port; El Anfoushy Ptolemic Tombs; Commercial area in the Turkish quarter; Abu El-Abbas Mosque; Anfoushy Fish Market; Fort of Qaitbay.

Fig. 10 Map showing the study area.

Alexandria. The Mediterranean Sea presents its waterfront to the north. The study area will focus on the coast which represents The Anfoushy Public beach and the costal hinterland that represents Kasr Ras el Tin Street which leads to Ras El-Tin Palace, which is allocated for the reception of official delegations of the state. It also holds the function as a main gate to the Turkish quarter, which unfortunately began to gradually disappear due to the neglecting of this area's building. Any waterfront development process goes through different phases. This study focuses on the pre-development phase.

5.1. Analysis of Bahary Waterfront

Bahary has a waterfront scenic path, with prominent views of the Anfoushy Bay and Ras El Tin Palace. It is also with a historic background as it is the main entrance to the old Turkish Town of Alexandria, which includes a unique urban pattern of houses and streets. The analysis of study area is based on some principles collected during the theoretical part which focuses on the principles of waterfront development.

5.1.1 Access and Linkages

The waterfront stretches 900 m along the sea and with variable width, from 25m to 37m, joins the El Gish Road in the east to the very narrow streets of the old city in the west, and it is the only main street which serves the connection of its surrounding area land uses to the rest of Alexandria. At the southern street perimeter, there are more than 30 T-intersections with small and poor local streets, mostly with dead ends as well as some secondary streets like Sidi El-Hagary Street, Safr Basha Street, and Sidi Yacout Street. Also, there is a promenade along the sea but it does not encourage the public access and it was lined by palm trees to provide shade and there is a safety railing and lighting units along the walkway. The waterfront can be accessed by different means of transportation: public bus, private car, horse cart, bicycles and boats. The city tram, of which the network serves the old city, runs with other traffic in the middle of its right-of-way. Hiring boats or horse cart are considered as tourist attraction. Furthermore, the waterfront esplanade leads to various activities and attractions such as historical buildings, restaurant, the Anfoushy cultural center and the boats workshops that had run for decades.

The presence of variable activities and street level uses on the pedestrian paths are important to achieve walkability and vitality in the city

In addition, multiple accesses to the waterfront provide a good accessibility to the different landmarks in this areas: Palace Ras El Tin, The Anfoushy fish market and the boat workshops are connected by the Kasr Ras El Tin Street and el Morsy Abo El Abbas Mosque is permeable by Sidi Yakout Street. Walkable waterfront with activities are necessary to connect various destinations in order to attract people to the waterfront and achieve a desirable waterfronts.

5.1.2 Uses and Activities

The waterfront has a variety of land uses along its perimeter. To the north (waterfront), there are a lot of consecutive land uses; such as the Anfoushy Cultural Center, boat workshops, local club, children education centre and a huge sand public beach that serves as an attractive recreation area. The other street side has mixed land uses with residential area. The residential area contains ground floor cafes and restaurants with some street seating. Retail consists of many simple commercial shops and other service-related storefronts that add to the unique traditional style of the area and to reach unique designs to the Bahary Waterfront only. The most effective way to create a livable city and make an attractive urban form is by increasing activities. There are a lot of activities such as social and sports club, cinema and services like hospital and mosque. In addition, the waterfront thrives day and night throughout the year by integrated seasonal activities during different feasts that make users feel welcome and safe.

5.1.3 Comfort and Image

Bahary Waterfront has a different experience, due to its historical background and uses that create a strong sense of place. The Anfoushy citizens are enjoying the waterfront at the sunset and at night-time to meet each other. Fishing and boat industries are the primary activities in this area. The sense of smell and taste are characteristic to the study area and are shaped by the primary activities as the space can be understood through the sense and create a mental map. These senses are used to clarify and survive the life of the urban space to provide a unique and dynamic place to attract a range of people, they also should define people's experience and keep people coming back. By analyzing the buildings conditions, there is no

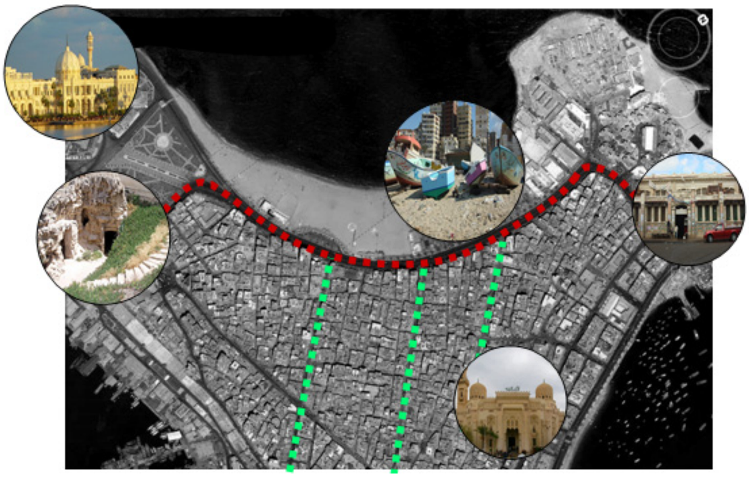

Fig. 11 Map showing the site accessed by the different paths of the study area.

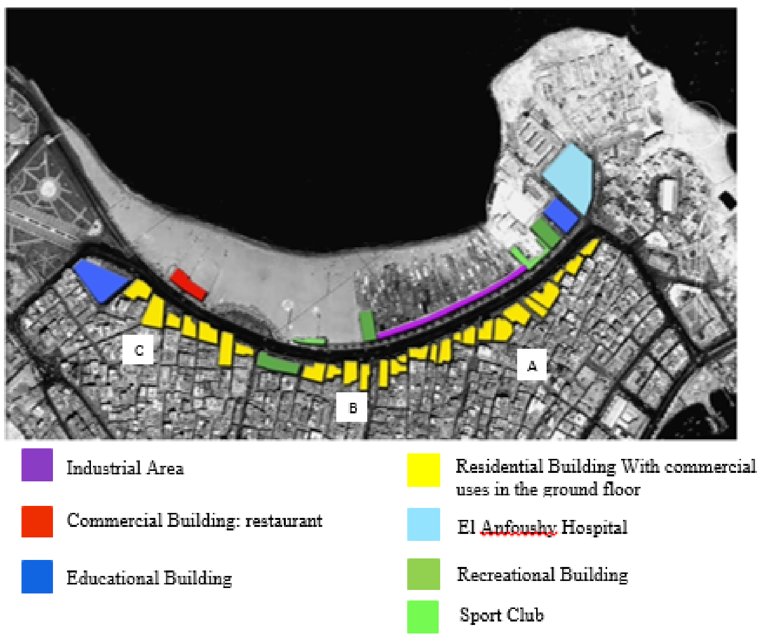

Fig. 12 Map showing the land use of the study areas.

Fig. 13 The study area is divided into three zone to show the different land uses.

Fig. 14 Pictures of some activities by order: Anfoushiya Fish restaurant; Farag Fish and El Sheikh Wafik restaurants; Boat Workshops; El Anfoushy Cimena; Marine Sport Club; Child Club.

Fig. 15 Pictures showing different images in Bahary.

architectural style and character and buildings do not respect the building regulation. Although landscape element, amenities and furniture like seats, lighting units and sheds are used to provide comfort, social interaction but they are not well designed and organized. Also, there is a lack in parking areas.

In Kasr Ras El Tin Street, the Mediterranean Sea shore at Anfoushy Bay forms a strong edge. Also, the main path of the study area is the Kasr Ras El-Tin Street that connected Ras El-Tin Palace, The Anfoushy Cultural Centre and the Ptolemaic tombs which present the landmark of the area. In addition, small districts are formed along the street such as El Sayala, El-Hagary, Armed Forces residential compound and Bahary areas. At The Anfoushy Fish Market, there is a node with a number of visitors.

Fig. 16 The primary job in this area.

5.1.4 Sociability

Fishing and boat industries which are the primary activities, give a local identity and character to Bahary and offer a lot of job opportunities to the resident. Also, the old fish market is one of the main heritages building in this area. In addition, there are a lot activities, such as restaurants and marine center, based on the primary activities.

6. Conclusions

After analyzing the study area of Bahary Waterfront, several conclusions of the existing conduction have been highlighted, and some problems can be reached.

6.1 Problems related to Access and Linkages

Due to the variety of mean of transport in the study area, the movement is not organized and overlapped.

The secondary streets are very narrow and in a bad condition

Public access is not comfort and safe due to the lack of integration between the two sides of the waterfront.

6.2 Problems related to Uses and Activities

Although the district is considered as one of the important archeological site, but is not given enough attention.

The recreational uses located along the waterfront are very poor and limited.

The uses and activities are not homogenous distributed along the waterfront.

There are a mismatching between the function and activities of the area.

6.3 Problems Related to Comfort and Image

Some of the buildings are in a bad condition and do not have architecture style and details.

The parking areas are not enough and they are along to the waterfront.

The palm lined the promenade, impede the pedestrian walk.

The street furnitures like the sheds and seats are not well arranged in the area, and there is a very long distance between the street furniture.

6.4 The Absence of the View of the Waterfront and the Public Art

Although this area has a different sense and very rich of opportunities but it is not well exploited.

6.5 Problems Related to Sociability

The public goals are not achieved.

The management of the community vision does not take in consideration the public goal.

7. Recommendations

According to the previous results and problems of the case study, the following recommendations are set to improve the Bahary Waterfront:

(1) Access and linkages recommendations

• Providing public access to the shoreline that is supported by corridors and that establishes convenient connections to the other side of the waterfront and to adjoining streets that extends from the street grid of the city;

• The creation of public transit routes that provide easy transit to the waterfront from the city center;

• The creation of “nodes” along the waterfront and providing pedestrian linkages between public access nodes;

• Separating the movement of the pedestrian and vehicle by changing their paths and increasing different crossing points between the two side of the waterfront and bridges and tunnels;

• Adding a bicycle lane way and large promenade with well organized street furniture’s;

• Creating floating promenades and platforms to define a new path and edge with the waterfront;

• Developing the secondary streets that connect the Bahary waterfront the city center.

(2) Uses and activities recommendations

• After analyzing the activities and the uses of Bahary Waterfront, it can be divided in three zones which are: Zone A represents commercial and residential zone, Zone B is recreational and residential area and Zone C is a historical area as it is can approach to the Ras el Tin Palace;

• Arranging of productive and compatible activities with the renewed context to ensure the diversity in the zone’s economy;

• The water sheet and the shoreline should be reserved for water uses and public access;

• The ground floors of buildings should to reserve for recreational uses and the facilities of public accommodation;

• Devising a master plan of land use that blends the values of old and new structures and uses of Bahary.

(3) Comfort and image recommendations

• The using of the landmarks of this area revived the interest of the city’s heritage;

• Reinforcing the attributes of the central area which is closely linked to the heart of the city;

• Creating well organized street furniture along the waterfront such as seating, shelters with good and comfortable material;

• Providing parking areas away from the waterfront.

(4) Sociability recommendations

• The public participation of the local population is important to achieve their needs and to make their own environment with the purpose of keeping alive the memory and preserving the identity of Bahary;

• The need of coastal management to address to the unplanned urban growth to ensure the harmonious development of human activities while protecting the submerged remains of the ancient city.

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The Architecture of Value Thinking and Pneuma in Housing Associations

Jan Veuger

Noorder Ruimte Centre of Applied Research on Area Development, Hanze University of Applied Sciences, Groningen, 9747 AS, The Netherlands

Abstract: Housing associations make too small a contribution to society, the government has to step in too frequently because of maladministration, and the associations' executives are often unaware of the far-reaching impact of their decisions. These are the conclusions of new academic research conducted by Jan Veuger of Rotterdam School of Management, Erasmus University (RSM). In the author's dissertation, he asserts that in numerous cases, there is no correlation between social and financial objectives. The Dutch House of Representatives debated the results of the report Ver van huis from the Parliamentary Committee of Inquiry on Housing Associations in early December, 2014. The research that is being carried out at the moment is constructed in a manner that if we understand something about value thinking and what underlying motivation is, an approach can be deducted that will allow us to control them. After the introduction, an explanation of the theme of the research will be given and the choice for a four-phase model with a deepening as to what value(s) is (and are). From the perspective of the four-phase model, the emphasis will be put on the socialization and thinking capacities, and parallels will be drawn between the values within the four-phase model, the examined values, and in specific, public housing corporations.

Key words: Values, social housing associations, organization, control.

1. Introduction

"We can't solve problems by using the same kind of thinking we used when we created them", Albert Einstein once said. This statement characterizes examples from 2009 of possibly mismanagement within building corporations and politics, of self-enrichment, and self-overestimation. Is all the media attention coincidental and are all these cases just incidents, or are the contour of a trend emerging? Can we still rely on sensory perception, value creation, integrity and vice versa? Are (new) rules of the game sufficient to rely on? Is supervision sufficiently regulated?

2. Design/Methodology/Approach

After extensive exploration of the literature and Ph.D. studies on the period from 2005-2009, the research design inspired was based on the grounded theory, which has a certain bias as a result of the extensive literature study. In the line of thinking of the grounded theory, interviews with directors more or less contracted uninhibited according to a narrative method. Afterwards, these interviews, independent of the researcher, thematic and labeled by a single Delphi method should be submitted to an expert group which created a storyline. The results of this Delphi method have been submitted to a peer group of directors. Then these conclusions in a survey presented to 60 selected directors and the subsequent conclusions. There has thus been more than a triangulation of research than just interviews, Delphi method and survey. Hypotheses are thereby omitted because of the difficulty of fitting in within the chosen research design inspired by grounded theory.

Corresponding author: Jan Veuger, professor; research fields: real estate. E-mail: j.veuger@corporaterem.nl, j.veuger@pl.hanze.nl.

3. Responsible Corporate Governance: A (Dis)illusion for Public Housing Corporations?

"*Value is determined by an opinion and insight into the range of the human brain, determined by its direction, its interest, its behaviour, and is expressed in a thought form in order to satisfy a need.*"

Corporations are in essence not profit-driven organizations, but consciously allocate means towards societal goals. It is difficult to name these goals and to compare them with each other. Can we measure or guide them? As long as there is no objective method to compare goals, these kinds of questions are difficult to answer. There are different streams of thought concerning goals, as to what is important, as to what has priority and as to what influence can be exerted. The complexity of cooperation, of efficiently resolving problems is enormous. The difference between in- and external, long and short term is becoming smaller.

The quote by Albert Einstein "We can't solve problems by using the same kind of thinking we used when we created them" makes that managers feel at times out of balance, without knowing exactly why. Many organizational management instruments, as, for example, the Balanced Score and INK, deal with a non-active content choice, and do not deal with choice or behaviour. The risks of an instrumental and a mechanical approach of the tools are considerable. It is crucial to see which relationships are at stake and how the process of influence-taking by stakeholders in the dealings of an organization, in the decision-making as well as the implementation, can be guided. This can be done through the lens of corporate governance thinking by societally justifying, the horizontal responsibility, the vertical supervision, and value-guided management. A solid and professional style of governance is essential to social entrepreneurship. Self-guidance as a point of departure for promoting professionalism plays an important role in efficacy, efficiency, and transparency. Additional optimalizing in- and external control does not mean a new organizational infrastructure. It is about an improved integration and coordination of management methods and techniques (co-existence and tolerance) that the organization (already) uses.

The question is also whether developments surrounding a new arrangement between corporations and government will result in a solution. After all, the work is complicated, because social entrepreneurship is too complex to be able to combine different goals. Supervision would have to be external, from a board of supervisors, and in a such a manner that the board at least oversees the spectrum of the total policy, which has sufficient focus, maintains it, and heads towards the goals of the enterprise and the targets that are derived from it. The use of instruments offers possibilities, but is most definitely not a guarantee for guidance and precluding integrity. Apart from that, visitations, by which the minister could not order interventions against individual corporations, could be an important tool for the new authority. Intervention would only occur on request of the authority. It is remarkable that neither the proposal of the Commission New Arrangement between Government and Building Corporations nor the law proposal on Social Entrepreneurship, has resolved/improved everyday praxis, because it deals with behaviour. An integration of these new instruments should at least be of relevance.

4. Ethics, Profession and Organizational Limits

Collins [1] posits that companies—that were in a comparable situation as their competitors—all of a sudden accelerated and in a period of 15 years explosively grew. What differentiated these companies from others in the same sector were timeless factors: leadership, hiring the right people, continuing to see the hard facts, having an answer to three framing questions (what are you best at? What do you believe most in? And what is essential to your continuing economic survival?), possessing a disciplined organisation culture, attaching (selective) importance to technology, continuously and persistently working without revolutionary break-through moments. With these capacities, one can grow towards excellence. Laws have often evolved insufficiently, and allow for exceptional or unacceptable behaviour. Self-regulation can be an addition and the role model of the organization—and more importantly, that of the people—can be of critical importance. It must be noted that integrity is not facilitated by merely complying with the rules of an organization, in compliance with prevailing laws. Relativation is of certain importance, but at least as important is working on the morality of the involved professionals.

A further trend is that the contours of organizations are becoming more elusive. Thinking of chains through the walls of a company is an important theme at the moment [2]. Apart from that, a changing area of tension between competition and cooperation can be observed. When is someone a competitor and when is it possible to cooperate with someone? Do we share the same vision with regards to a common goal? Within organizations, there is often a high degree of loyalty. But what about the limits of the organization? Authority in a chain is often much more complicated and diffuse. It is also about letting go of thinking along the lines of theory that is applicable to financial and political markets. To develop a specific theory for managing and investing in real estate [3], custom-tailored to the specific characteristics of the real estate market, the different types of real estate investments and their actors are being advocated [3]. A core idea is that research and transmitting knowledge are urgently required. For the involved management, it is not possible to control processes, for which they are responsible, in such a manner that over several years, the desired results will be achieved. Understanding the value of these results is also not easy, because value manifests itself in different shapes. Until now, there has been insufficient multidisciplinary cooperation in the field of research on real estate [3]. Each of the previously mentioned sciences is relevant to real estate management. Certain demands with regards to the character of a person and his attitude towards work are asked from a professional. The following can be named: a critical attitude towards one's own performance and that of others, the willingness to carry responsibility, a high degree of commitment, taking initiatives, and striving towards greater efficiency and efficacy. A multidisciplinary character of real estate management forms a bottleneck in determining as to which insights—also with regards to their context—must be gathered.

5. Value Thinking in the Four-Phase Model

The four-phase model by Hardjono is in essence a framework for a common language and a tool in answering the question as to which direction an organization should head towards. The model is the result of a number of organizational principles that structure points requiring attention, possible choices and interventions. It gives the own thinking procedure of the organization a shape so that—independent of the question as to whether change is desirable—a responsible choice concerning organizational interventions can be made. The model does not, however, give an answer as to the reason of change, nor does it give an explanation as to whether a chosen approach brings about change and as to whether this occurred in a professional manner.

Hardjono first formulated the four-phase model, and wrote the dissertation: "Rhythm and organization dynamics: four-phase model with clues for organizational intervention in order to increase efficiency, efficacy, flexibility and creativity" [4]. The four-phase model is the result of several studies, theoretic models and practical experience. In particular, the model gives direction in accumulating competences, and can consequently answer for the actions that led stakeholders to opt for a specific choice of direction. The model, therefore, presumes that an organizational improvement occurs because different modes in management follow each other not linearly, but cyclically [5]. It is, thus, increasingly desirable that organizations are sensitive—and, thus, anticipate—towards social circumstances. Due to its scientific foundations, the idea of giving direction to competency accumulation, anticipating social circumstances and making actions more transparent, the four-phase model is the most suitable model to use as a basis for this research on value thinking and managing. And that is why the four-phase model was chosen as the basis of value thinking in this research. "Using the four-phase model is only useful if there is awareness that quality care is a matter of survival" [4].

6. Values in the Four-Phase Model

In the processed management theories by Hardjono [4], the sensitivity towards values is determined by a value hierarchy, which makes it possible to explain human behavior. The thoughts of Lievegoed concerning the evolution line (pioneering, differentiation and integration phases), along which organizations should evolve [6] and the cloverleaf as thinking pattern for structuring an organization [6] have influenced the four-phase model. In the reasoning of an integrated organization that the manager needs to manage and control, it stands at the centre of the organization surrounded by four, equivalent sub-systems. On these crossroads of information and communication paths, it directs processes, management through information processing and distribution, external relations and marketing, supply of resources and people [6]. In the development of the four-phase model, it has been tried to regard the evolution lines—that were worked on in the past—as a whole. In the search for values by Hardjono [6], he comes to a classification of values in four different levels, which also labeled a hierarchy of values. These values are independent of each other, but have a remarkable relationship with each other in the sense that each right of existence is assured by the presence of the precedent one. This can be well interpreted through the use of a metaphor, like the one described by Pirsig [4] of an open book in a PC (personal computer) and to transfer this metaphor to living in a home. The computer is an object made up of dead matter, and thus forms an organic value. This matter is necessary to host the hardware with which the hardware can enable the management of the software, and thus the organic value is formed. The hardware has thus become a condition for the functioning of the software, the social value. Noteworthy is that both hardware and software can exist separately, but that software cannot be used without hardware and hardware retains its value, but not vice-versa. Through giving meaning to software, intellectual value is created, with a comparable relationship as the one between software and hardware. Pirsig's value philosophy, which is located between objective and subjective values, is not the only one to attribute a hierarchical order to values [4]. Regarding the intellectual value as the highest ranking value relates to the highest possible virtue of considerations of cultural philosophers such as Hegel: the pure being, self-consciousness, reason, mind/religion, pure knowledge.

By applying a metaphor of living in a home for the value(s) of a corporation, one needs to consider the anorganic value of the stones as being necessary for the organic value of the real estate corporation. This form of management of the stones is a prerequisite for the use of the social value with which a specific applicability has been created, the value has increased and a new value was added. The stones have thus become a perquisite for acquiring a specific applicability, the social value. Noteworthy in this relation is that it can exist separately, but that the social value cannot be used without the stones. The pneuma [7] of housing can only function if the ensemble of stones, management and specific application possibilities operate as a whole, through which as a whole it generates a specific intellectual value.

Here, a relationship between pneuma and social value exists that is comparable to the one between management and application possibilities. Herewith, the connection is made between values, individual needs and organizations; an organization being defined as a co-operative union between individuals that are driven by their individuals needs [4]. Apart from the seven needs of Maslov, Hardjono identifies two further needs, that of knowledge and understanding. By translating this to public housing corporations, there will be no motive for an individual to be part of a corporation. The presence of pneuma is necessary for all values as organic, anorganic and social. The congruence of individual and organizational targets appears to have great attraction on the individual; by which the relevance of congruence is recognized and loyalty and commitment increase. The criticism of Maslov's theory that the hierarchy assumes a successive evolution, in which the satisfaction of the preceding level leads to the next one, is recognized by Hardjono in his four-phase model by giving attention to all forms of capacities. Sacrificing a preceding satisfaction for a higher value is considered to be unethical. The existing right of a corporation is determined by its organic value, the shape of its organization. But the question is whether the social value of specific application possibilities and the intellectual value are being recognized by its environment. The measure of direction communication in between values as well as their evolution is also recognized by Lievegoed [6] in his description of pioneering, differentiation and integration phases. The transition from one phase to another generates attention for cooperation, external orientation, serving function, and is finally directed by the intellect, with the cloverleaf as thinking pattern in the third phase of integration [6].

7. The Value of the Four-Phase Model

With regards to the reasoning of the four-phase model, it is important to realize that one is dealing with an interconnected whole of people that exercises an influence on each other. The organized collaborations of the expressions of the organizations in the form of power and numbers are to be interpreted as the organization. Perceptible expressions are not always rational and do need to be interconnected [4]. Through a certain degree of repetition and stabilization, it is possible to recognize a structure; one which people avoid if it does not serve their own goals. The evolution of people, that is also shaped by outside influences, thus, also forms the organization. In the context of the four-phase model, the existence of the structures is thus not neglected [4] and are, therefore, also found in the model; although Hardjono prefers to think in terms of processes. The subjectivity of the model is recognized, but through dialogues in the experience years of the model, a deepening has taken place and the model has moved in the direction of intersubjectivity. It has, thereby, not become a model of an objective description of the reality. Because the model simplifies reality, it can be criticized [4]. As Hardjono describes, the four-phase model is characterized by: "subjective knowledge as science-philosophical basis and regulated change as possibility for change" [4]; he, therefore, uses fundamental conditions, namely: (1) that human action is based on significances; (2) which result from social communication; and (3) which are handled and altered in a process of interpretation [4]. It can be assumed that if this philosophy is translated to housing, the act of living in housing only acquires value and thus significance if it is referred to in a sociological sense. Housing only acquires a position in the dealings between people if you can do something with it. The different capacities within the four-phase model do not only influence the value of the concept of housing, but depending on the orientation direction that each capacity will also change its form. Because of these different orientation directions, different play grounds become visible, that can be disrupted; these spaces and disruptions can change the focus of attention.

Therefore, the four-phase model can be applied as an interpretative instrument. Through the development of knowledge and thus the development of the organization within the context of value thinking within a hierarchy of values, the professional is introduced. This professional is described as “a person who with the help of creativity and application possibilities uses scientific knowledge in solving value problems” [4]. The value problem is defined here as the amplification of this value by designing, conceptualizing in advance actions, and—parallel to that—thoughts as to how these actions can be adjusted if necessary. The value of the four-phase model resides in its helpfulness to “design an intervention that solves a unique and specific problem so that an increase of value takes place” [4].

7.1 Value Increase with the Four-Phase Model

The question to ask is whether we must speak of value increase or value addition. Value increase presupposes that there is more of the same. In addition, on the other hand, that something is added to another, and that it does not need to be the same. Furthermore, the question can be added whether what constitutes value for whom? The questions cannot be answered without assuming which exchangeable desire is at stake. The four-phase model is composed of four different kinds of capital instead of values, because the aesthetic component that value entails can be linked to norms. In the use of the term capital instead of value, Hardjono [4] leaves the value doctrine of economic theory that has evolved into a value philosophy. Using this philosophy, it is not just a matter of an objective value judgment, but also about recognizing an absolute, eternal value outside the historical and social value awareness. In the context of the four-phase model, value is not merely seen as a significance as to whom belongs property or is entitled to it; the notion of value is also placed in the scope of this property. The question that can be asked is whether the scope of property determines the value, in relation, for example, to the market share, in the absolute sense, of the number of houses in the entire Dutch real estate market, or the exchangeability of the desire, in which the desire and the capital to make. The four-phase model, therefore, focuses on the definition of the term capital with its double meaning, i.e., the possession of property and the ability of what one is capable of doing. By speaking of property within the context of capital, it immediately becomes clear where the property is to be situated. This stands in contrast to the term value, because value has a different meaning for each individual involved, and is accordingly expressed differently.

8. Orientation on Socialization and Reasoning Capital

The ability to cooperate constitutes the social capital in the four-phase model which relates the most to the individual needed to be part of an organization. The organization represents for the individual the social need, and can provide the individual with this. By integrating this, one can lean on the appreciation of an individual. The socialization capital, therefore, determines how the organization determines its architecture; this genetic code can be regarded as something that can be changed. Through a mutation of the genetic code, the architecture changes, and therefore the genetic code is the key to changing.

“The reasoning capital is the collective result of personal growth and intellectual development of the members of the organization” [4], and therefore enables the organization to maintain a structure. The reasoning capital thus has a collective character and presumes that all it encapsulates all prior experiences. In the four-phase model, the reasoning capital is related to notions such as empathy, plans, insight, synergy, self-knowledge, behavioral norms, reflection capacity and inventivity. If we apply these notions to the developments within the world of housing corporations in the last five years—and in particular what the literature has written on this subject, a picture of corporations and their reasoning capital emerges. Without reasoning capital, it is not possible to increase the socialization capital, whilst the presence of socialization capital constitutes the basis for the reasoning capital. Due to this mutual interdependence, Hardjono posits that the reasoning capital is the source of everything. It can be observed that in the world of housing corporations, the dialogues concerning the developments and the value of the material capital—the stones, and in many the commercial (in)capacity reached above all the media, but not so much the socialization and reasoning capital. The presence of reasoning power, on the basis of societal appreciation, is referred to by Hardjono [4] as the intellectual capital, also called reasoning capital. The relation between all four capitals of the four-phase model—and in particular the way it has earlier been adapted to the housing mission, can be represented in four circles. The mutual interdependence and interchangeability is thereby expressed, and the whole can be increased; each individual condition, independence and capitals must be present.

The circles of the four value capitals—the first layer of the four-phase model, give a balance of works in different directions, and need to be in balance among each other. The capital increase finds it way along a new layer in the four-phase model, in the two axes, internal and external orientation, and forms the primary orientation directions for value increase or increase of the capital. Hardjono [4] posits that: (1) an organization needs to find a balance between internal and external orientation; and that (2) organization needs to find for itself a balance between an orientation towards control and an orientation towards change—the second layer of the four-phase model. In general, one can choose to adapt management theories for value addition or value increase [4]. Giving attention to this leads to concrete results with their own characteristics, and forms the third layer of the four-phase model. Differently formulated: if we want to understand the concrete results of housing corporations, we need to examine their orientations. A change of direction in orientation is influenced by interventions which are iterative. On the different capital levels, different interventions are possible; the condition for this is that each orientation direction gives—related to a specific capital, a specific key for intervention [4]. For the socialization and reasoning capital of housing corporations, the interventions from the perspective of orientation on change—internal and external orientation—will be more closely examined.

8.1 Interventions in the External and Internal Orientation Context

The housing corporations market can be regarded as an open system in which marketing procedures can be carried out on an consumer market: the external orientation. Several questions need to be questioned in this context: under which terms and conditions do we offer our houses and services? How is the social housing (Fig. 1) market segmented (and did we do this)? Who and where are our tenants? These are questions that can be answered if there is an external orientation. If these are brought into connection with the four capitals—in particular the socialization and reasoning capital, keys for interventions emerge. The creation of a network is the result of an intervention on the socialization capital, based on the external orientation. Herewith, the housing corporation learns to anticipate in the context of a social environment, and there is a greater willingness to take more risks, and entrepreneurialism is increased. The striking power of the entrepreneurialism of a corporation can come under pressure by the social setting.

The intervention of anticipating societal developments has an influence on the reasoning capital of the corporation. Empathy will have a positive effect on the other capitals, and will lead to plans based on strategy. Creativity becomes apparent in the form of lateral thinking [4], but can also lead to the trap of respect earning admiration with no increase in turnover. The discussions in the period of 2009 concerning the right of existence of housing corporations can be placed in this context. An extremely external orientation can lead to oversensitivity of housing corporations.

Means for internal orientation are cohesion/morality and information management/communication [4]. Cohesion can be regarded as a socialization value through the development of a social system, in which morality can also be attributed to the reasoning capital. Internally, questions such as “as how far are we corporations?” and “What is the identity of the organization and what does it contribute to the organization?”, answering these questions, as well as the question how the socialization capital of a corporation can be controlled, lead to the creation of an organization with a distinct hierarchy, that eventually assigns tasks, responsibilities and competencies. Reflecting on these matters leads towards orientation on change, and contributes to the flexibility of housing corporations. The reasoning capital of the corporation can be increased internally by executing self-inquiry, which will lead to self-knowledge. Here, a certain tension between developing the reasoning capital and the external orientation can develop. By combing this self-inquiry with explanations and forecasts, the synergy within a corporation will be increased; synergy is here to be understood as the benchmark [8] for efficiency [4] with which the organization realizes how to deal with her reasoning capital. A too strong orientation of the reasoning capital can also lead to all energies being invested in this, not resulting in anything. In the period of fusions of corporations, this becomes evident in the fact that the external orientation decreases in such a period. However, through interventions on the internal orientation, a certain flexibility of the organization arises.

9. Interventions with an Orientation on Control and Change

One element of the economic engine is the structure of revenues and profit margin. Questions that arise in this context are: Where in the system of housing corporations are possibilities for profit to be found? Where do the margins come from? What has determined the size of the profit margins and are the most important factors influencing this? Answering these questions ought to result in a system of control, and might be able to change the said system. Through an orientation on control and should get to goal-oriented interventions. Creating a structure in a hierarchy forms a tool to assign tasks, responsibilities and compentences within the corporation and to avoid ambiguities. By influencing the yield of the social capital, the effectivity is increased. Controlling the reasoning capital thus takes place through explanations, forecasts, by qualifying the scope of the reasoning capital [4]. The flexibility and the adaptation ability are determined by answering questions such as: How alert must we be as a corporation react to value additions? How can investment programs be adapted? Where is resistance against change to be found? Such questions are related to the control of different capitals, and thus refer to the reasoning capital of the corporation and its mobilization. Insight is, therefore, a prequisite for maintaining and increasing the other capitals. An extremely advanced orientation on control leads to rigidity.

The orientation on change has an influence on the innovativity and flexibility of the corporation with creativity and flexibility as a product [4], but also has its influence on the different values. The division into two distinct concepts such as internal and external orientation creates a kind of tension; this also applies to two non-overlapping concepts such as control and change: they cannot do without each other. Total control does not mean being completely open to total change, and orientation on change must be seen as proof that the housing corporation is capable of true renewal in terms of consolidating and increasing its existing capital. If the corporation is capable of doing this, then this will lead to a wealthier corporation where everybody will support new developments and ideas.

9.1 The Intellect of Solidarity, Sobriety and Inspiration

Solidarity [9] is more than promoting specific interests on a local level or in the short term, and it is more than making donations to charitable organizations. The content of this concept is determined by the Christian social teachings that are based on a personalized notion of man; man is more than an individual and rational being that stands in relation with others. Its relevance becomes apparent if it stands in relation to others. In the context of this concept of man, the Church distinguishes two fundamental principles: first, the immutable dignity of each human being, i.e. human dignity. This dignity is inviolable and requires to be respected; The second principle is complimentary to the first; the result of collective responsibility is not a sum of different interests, but the common good. The common good is aimed at creating a society [10] into which everyone brings inviolable human dignity and truly everybody shares responsibility for others and the whole. The government needs to be involved in a continuous dialogue with the civil society to create a structure of justice, and people and groups need to create content for the common good. This emotion generates the value that must be measured.

Solidarity thus brings with it a responsibility that transcends time and space. Making responsibility explicit and the desirability of this is necessary to point out problems that derive from the mission of housing that emerge in areas with a mission. Through the availability of the financial means that wealthy corporations protected by them, through mediating problems in the best possible manner and thereby protecting their own wealth.

Every human and every generation have the right to fully participate in a society, and thus participation is a condition for solidarity, and thus a duty, apart from the right. Thus, the concept of subsidiarity—the manner of organization or rule in which tasks are assigned in to a higher level for matters that cannot be dealt with on a lower level—needs to be applied here, because personal responsibility cannot be delegated nor is it transferrable. Thus, one cannot acquit himself from personal responsibility. In the case of shortcomings of this, the higher level has the subsidiairity duty to intervene in a contributive or replacing manner. Another condition for solidarity is moderation. One can speak of a right measure, if there is the right balance between human dignity and the common good. All other interests are subordinated to this, and it must be presumed that private wishes and ambitions are to be relativized. The self-cleansing ability to contribute an indispensable piece to this responsibility is thus essential in order to make a contribution to the problems of housing. The "soul of socially responsible entrepreneurialism" lies at the core of the spirituality, the pneuma, the fourth P that Van Luyn introduced in 2001 and which the Social-Economic Council recognized. By inspiring people consciously and in a deeper sense, they become more connected with each other. Through inspiration and acting accordingly, people also become mutually connected with each other [4]. Without inspiration and the spirit, things does not work, and "the fire" lacks. And thereby a current of three movements of our time becomes determinative: solidarity versus individualization, sobriety versus economization, and spirituality against secularization—unchaining the spirit in which the housing mission was meant.

10. Value Thinking

The answer to the question as to what constitutes value is partially determined by the academic perspective with which one looks at value. An economist look at and defines value differently than a philosopher or a sociologist. Value thus knows many modalities, and is an indication of a relevance of something, and actually reflects how big the relevance is to a person or what relevance a group attaches to it in order to get it: a(n) (real estate) object, information, a service or a right. The question is how one can look through different lenses of value—may be a new—picture as to what value is and how an interpretation can be given as to what value can be. This has been done through a number of lenses, which will be discussed in detail in the next section; the exchangeable desire is a synthesis of the different lenses. One lens that was used is the report entitled *The Benefit of Values*, value thinking according to the Social-Economic Council [11]. This report is the result of a question by the former cabinet concerning the growing interest in social entrepreneurialism. The other lens is by authors of Enterprise and Society [12] who used the scientific responsibility, as well as the insights from the social positions they have fulfilled. In addition to that, other lenses were used to look at value thinking in the contexts of philosophy, ethics, axiology and anthropology. Looking through the lenses of real estate and value-based management at value produces different insights. Finally, as a last lens, value thinking from the perspective of the origins of housing corporations was examined; this section is titled consistency after the self-employment. Looking through different lenses, with all its different perspectives, has generated an insight concerning exchangeable desire.

10.1 Value and Values

The question is whether values can be thought of outside of a context. Are their universal values that can be applied to each context, and does one need to take into account the right of existence of values? Are all values equal, or is there a pyramid of values? And will this pyramid of values be arranged differently tomorrow, and if this is the case, are we speaking about a decline or a shift in values, in which people do have a value awareness, but in which some values become more important than others? A paradigm arises by pronouncing a statement concerning value and decisions: it is not difficult to take decisions, if one knows what values are. On the other hand, one can presume that taking decisions influences the value. And taking decisions can be difficult.

Looking at entrepreneurial value and in particular the value of social entrepreneurialism, we can posit that values of companies have an external dimension value (the market) and an internal dimension value (the sum of loyalty and motivation of individuals). In his article, Jagersma [13] writes that entrepreneurial value in particular is the result of three elements: First, it is the result of the individual values of influential employees in key positions on several leading levels; second, the history of the company; and third, the context of the sector in which it operates. The most interesting aspect of his theories is that two elements are given: the history and the sector. The history is a fact that cannot be altered, and the influence of a company on its particular sector is almost impossible to measure. What remains are the influence and role of the key positions of the leading employees. They can achieve change by adjusting the direction of the hardware: organizational structure, strategy, systems and processes. But they can achieve the most important adjustments through the software: the company values. A new direction with new goals must be supported and implemented by individuals. The (new) company value constitutes a bridge function between the non-changing personal goals of individuals and the altered company goals due to change of direction. If the company values do not change, the company heads towards a treacherous pool of red numbers. The company value—determined by its individual values, is thus a raft on which the company floats. Or in the way

Jagersma defines value and values: "Values are necessary to generate value (profit respectively shareholder value). Companies have a problem if the values of a company do not correspond with the value that is to be generated (as formulated in the company goals). Value and values are two side of the same coin that is name entrepreneurial success".

If we now look at the value definition of the fourth P of pneuma as acting according to the spirit, and the three different levels of the subjective, objective and absolute spirit, and apply these to the key elements of the Social Economic Council's report on socially responsible entrepreneurialism, we get to the following definition of socially responsible entrepreneurialism with value and values.

The company consciously focuses on the following four dimensions of entrepreneurial activities—profit (the economic yield), people (the consequences for people inside and outside of the environment), planet (the effects on the natural habitat), pneuma (acting in accordance with the spirit)—and thereby contributes to the long-term social welfare. This is a relation with the stakeholders that is maintained on the basis of transparency and dialogue, and in which an answer is given to justified questions asked by society.

10.2 The Fourth Era of the Housing Corporation: Pneuma

The developments of an institution that was allowed by the law, such as a housing corporation, can be divided into three periods. The first one that lasted until the end of the Second World War had diverging goals:

"Housing was not just a health measure, but also pedagogic one; it concerned morality and social integration" [8].

The second period, after the Second World War, was marked by the reconstruction of the Netherlands; the government played largely the goal of director. The arrival of secretary of state Heerema marks the third period; he layed the foundation for a policy reformation with his key note on "housing the nineties". Initially, this reorganization was carried out with strength; the result was that the offer guidance of the government disappeared almost completely. One of the consequences of this was the self-employment of 1995; the ties between government and housing corporations were severed. This was done with the expectation that Heerema's trend letter of 1993 in which he announced: interest increases would generate enough means to fulfill the social mission of building and managing [8]. Van Os [14] assumes, therefore, despite the recent discussions concerning capital, supervision, governance and regulating the sector, we are still living in this third period. The critical question that can be asked here is whether we are still living in this third period, but maybe should evolve towards a fourth period, the intellectual capital. The question that Klamer asked himself [12] is whether social engagement is a new success factor, next to the three Ps of the triple bottom line: profit, people and planet. Recent developments in 2009 concerning integrity, professionalism and impact of acts result in the addition of a fourth P, principles or even pneuma. The basis for responsible entrepreneurialism is principles such as honesty, openness and good citizenship, a legitimation or license to operate. Compassion as a binding element seems more than necessary in today's society.

10.3 In Times of Reformation or Downturn

In times of the reformation or downturn of a company with social real estate, a law may apply that has not been researched so far, but is generally considered to be true: the law of Gresham, that says: bad money drives out good money exchanged for the same price. This law has been added to the appendix, and is here used as a paradigm for the real estate of a social real estate company. In his work, Visser (1995: 266-268) concludes that Gresham's law offers a useful perspective for the study of a broad scale of phenomena concerning instability in economic life.

The law does not appear to be universally valid, but Kindlerbergen (Visser, 2005) has shown that the law can be generalized in the sense that there is always the danger that the market all of a sudden does no longer accept the existing (price) conditions and that it will flee from one asset to another. The undervalued assets of, e.g., the real estate of housing corporations, is being saved and is kept as a capital object. See here also the discussion surrounding the increase of the income limit for housing corporations as a result of the competition case of corporations in the Netherlands. The relation between market weakness and rate is an application of purchasing power parity theory: if the quantity of houses in a country declines in value, then more houses are needed to purchase a specific quantity of a good or a market position, and the rate of the (weakened) house falls. Curiosity concerning the (currency) new developments makes that companies (humans) would like to maintain these new developments and will trade the old through the sale of existing property, which makes circulation more difficult. We draw here the comparison between the currency and Gresham's law. The content of Gresham's statements changed with introduction of the bi-metallic system, in which the full-valued silver and/or gold coins with a fixed price relation were

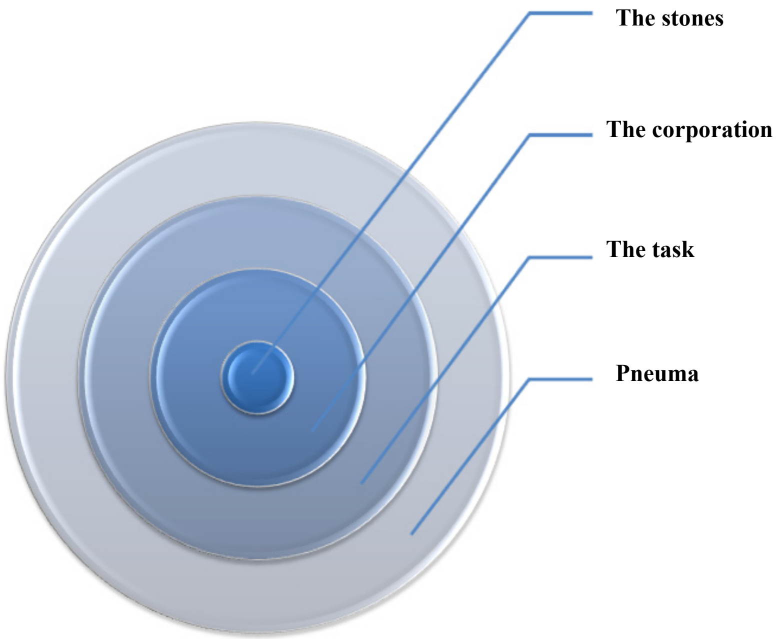

Fig. 1 Planning social housing [15].

Note: The stones (equipment capability and flexibility social property) as value driver is the material assets consist of the possession of social property and motivators like recognition and acceptance. Flexibility of the stones is in the manufacturability which is flexible and will remain;

The organization (return value, legitimacy and geographical scope) corporation as a value driver in the first instance by its geographic position and scope. The values assigned to a corporation on the basis of the capitalized results, its return value. Capitalized results are the proceeds of a given period to the value of the money that is involved;

The task (locking performance, socially conscious entrepreneurship, understood and broad orientation) is about the performance of the corporations secured, with conscious social entrepreneurship which is an important value driver. Being able to hear what the environment understanding with a broad spectrum of interests;

Pneuma (solidarity, guarantee structure, resilience and social housing policy) is leading in the principle of solidarity as enshrined in the constitution. Assurance that the housing is good or works within a structure is a float value in which they can stand up for themselves (resilience). Another value driver is the independent social housing policy that is about affordability, quality, and increase availability.

spent and could freely be “encouraged”, and price relations between gold and silver could change. One can speak here about a relatively content-rich, precious metal, the expensive money, and the cheap money that is the same as the expensive money, but with a lower metal content. In a modern economy, this only occurs during a deep crisis, such as a war or the collapse of the trust in the money that is circulating. Also, the contrary of Gresham’s “good money drives out the bad” (Visser, 2005) is true, if bad money is subject to difficulty and extensive to predict erosion: the dollarization of economies that are plagued by high and fluctuating inflation. In the article by Visser (2005:267-268), the impact of a crisis is regularly brought into connection with Gresham’s law. In a crisis, a situation occurs in which different kinds of money—read here the financial market of which the real estate market is a part of—are no longer regarded as equal. By exchanging en masse one kind of money for another kind, this becomes not always possible since the exchangeability is suspended. The story can be, according to Kindlebergen (Visser, 2005), the extended to the monetary sphere: it occurs when money, other financial assets and real assets exist, that can serve [14] as substitutes for each other in price relations. Of course, there is not always talk of an official price relation in which the market price relations deviate, but during a crisis, something similar occurs, namely a sudden alteration of the expectations which results in old market price relations no longer sufficing and holders, all of a sudden, considered overvalued assets wanting to get rid of their property. Kindlebergen focuses mainly only crises and instability. Gresham’s law in its reformulated version thus says “Two monies are unstable over time since the weak one drives the stronger into hoarding”. Furthermore, Kindsbergen posits that, in order to contain the consequences of a crisis, a tender of last resort is necessary, without completely letting go completely of price relations. In his approach, the emphasis has shifted from different currencies/real estate to portfolio management of economic subjects, and therefore Gresham’s law becomes a useful tool for the historic economist.

11. Conclusion: Inspiration and Exchangeable Desire

The most visionary thought can be determined with information resource and giving direction to the organization. The four-phase model works here in a supportive manner, and can thereby increase different values of an organization. Because “if an organization wants to survive, it will need to be visible in or anticipate the affairs that occur in a society” [4]. The metaphor of living in a house as the value(s) of a housing corporation is the anorganic value of the stones as matter necessary to incorporate the organic value of the housing corporation. This form of managing the stones is a prerequisite condition for the use of the social value; herewith, a specific application possibility is created, through which the value has increased and new value has been added. The stones have become a condition for creating a specific application possibility, the social value. Noteworthy in this relationship is that they can exist separately from each other, but that the social value is useless without the stones. The pneuma of social housing can only exist if the whole of stones, management and specific application possibilities operates as a whole; then a particular intellectual value is formed. The final steering process takes place on the level of the intellect; in this process of the transition towards the different phases of pioneering, differentiation and integration, attention is created for cooperation, external orientation and a serving function. Knowing and understanding as a desire next to other primary desires can be translated to housing corporations by realizing that when they no longer satisfy the primary relevance of social housing that then, there is no more reason for the individual to be part of the corporation. People will avoid the structure of the corporation if their individual goals are not served. From the philosophy that human actions are based on significances that result from social communication and that are modified in a process of interpretation, it can be assumed that housing only acquires a value—and thus, significance, if it is referred to in a sociological sense. The value of the object housing can be influenced by orientation direction with the four-phase model, and can, with this model, change the form of each capital; in this way, different playing areas become apparent, and in return, each space and breakthrough can shift the focus of attention. The presence of each capital and the mutual dependence as a interconnected whole is necessary for the personal and intellectual growth of people within the corporation; the reasoning capital as the source of everything becomes a prerequisite for success. If we want to understand the concrete results of housing corporations, then we must look at what the orientations have been. The reasoning capital of the corporation can be increased internally by introspection, which in return will result in self-knowledge. By combining this self-knowledge with explanations and predictions, the synergy within the corporation will be increased, and the flexibility of the corporations will be created. In addition to the reasoning capital, influencing the yield of the socialization capital can increase the effectivity.

Solidarity thus brings about a responsibility that transcends time and space. Explicating this responsibility and the desirability of it is necessary to point out the problems that result from implementing the social housing mission that result from areas with a mission. Through the possession of financial means the wealthy corporations have and that are protected by them by accommodating their problems in the best possible manner and thereby protecting their own wealth.

Herewith, the concept of subsidiarity—the way of organizing or the rule in assigning tasks that a higher level employs because they cannot be dealt with on a lower level—is applicable, because the own responsibility cannot be delegated and is not transferrable. One can thus not withdraw oneself from personal responsibility. In the case of shortcomings, the higher level has the subsidiarity duty to act in an assisting or replacing manner. One can speak of the right measure if there is a right balance between human dignity and common good. All other interests are thus subordinated, and it can be assumed that personal desires and wishes are relativized. The self-cleansing ability to contribute an integral to this responsibility is thus essential in solving problems in the social housing context. The soul of social entrepreneurialism resides in the spirituality or the pneuma of social housing as spirit in which the social housing mission was invented. The pneuma is thus not just a metaphor for describing human uniqueness, but also a description for a particular energy/dynamism underlying reality. The fourth era of the corporation can thus be qualified as one that is concerned with the maintenance, renewal and restoration of the original goals.

The critical question that can be asked here is whether the corporation has already arrived in the era of the pneuma, or whether it still needs to evolve towards this era in order to survive. In the period between 1950-2008, the spirit of the social housing has inhabited the institution called housing corporation. In times of crisis, a situation in which different opinions are no longer regarded as equal occurs within the housing corporation. Wanting to massively transform one opinion into another does not always work, because the exchangeability is abolished. By looking at housing corporations through the eyes of Kindlebergen, the following picture emerges. We are dealing with intellectual capital, money, other financial assets and real assets that exist and can be used as substitutes for each other in (price) relationships. Of course, there is not always talk of an official (price) relationship in which market relationships are diverging, but something similar occurs in a crisis, namely a sudden divergence in the expectations through which existing (market price) relationships no longer suffice and those that hold suddenly overvalued assets want to get rid of their possessions or their thoughts. In order to curtail the impact of a crisis, a tender of last resort is necessary, without letting go of the relationships. In this approach, the emphasis can be shifted from different opinions to portfolio management. The composed concept of social entrepreneurialism that it implicates entails—because of the financial and social yield—an implicit conflict, that can be prevented by admitting foreign capital with interest—and not only from a financial perspective—and not pay a return on investment. The legitimation should be derived from the field in which the corporation works and is responsible to, instead of the mechanism of national, political democratic control. The law on housing formulates a destination duty for the capital that a corporation manages and assigns the task of taking care for good and affordable housing; the government holds a large share of the decision power concerning how that capital is to be spend. Eventually, it is a matter of satisfying accomplishment fields. A better and lasting with other relations is seen by managers as a less important effect; this creates a legitimation gap concerning real authority and chain-partnerships. The outcome is considered to be important, but generally speaking, one is not familiar with the methods that are necessary for that.

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